US009154874B2

(12) **United States Patent**
Ura

(10) **Patent No.: US 9,154,874 B2**
(45) **Date of Patent: Oct. 6, 2015**

(54) **HOWLING DETECTION DEVICE, HOWLING SUPPRESSING DEVICE AND METHOD OF DETECTING HOWLING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 375 days.

(21) Appl. No.: **13/819,778**

(22) PCT Filed: **Feb. 24, 2012**

(86) PCT No.: **PCT/JP2012/001294**

§ 371 (c)(1),
(2), (4) Date: **Feb. 28, 2013**

(87) PCT Pub. No.: **WO2012/120815**

PCT Pub. Date: **Sep. 13, 2012**

(65) **Prior Publication Data**

US 2013/0156205 A1 Jun. 20, 2013

(30) **Foreign Application Priority Data**

Mar. 9, 2011 (JP) 2011-051623

(51) **Int. Cl.**
H04R 29/00 (2006.01)
H04B 15/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04R 3/02*** (2013.01); *H04R 25/453* (2013.01)

(58) **Field of Classification Search**
CPC H04R 3/02
USPC 381/56, 83, 93
See application file for complete search history.

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Primary Examiner — Paul S Kim
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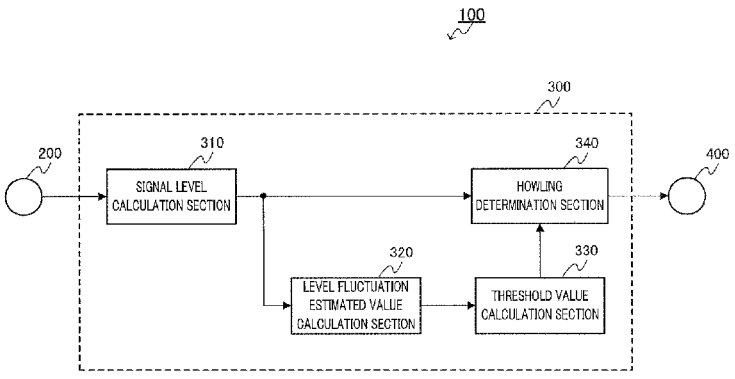
(57) **ABSTRACT**

A howling detection device capable of detecting the occurrence of howling with a higher degree of accuracy is provided. The howling detection device includes a signal level calculating unit calculating, from the input signal, an input signal level being the signal level of an input signal at each given time, a level fluctuation estimated value calculating unit calculating, from the input signal level, a level fluctuation estimated value being a value gradually increasing or decreasing by a given amount with time, a threshold value calculating unit calculating, from the level fluctuation estimated value, a level threshold value changing in accordance with the level fluctuation estimated value, and a howling determination unit which determines that howling occurs in an input signal under the condition that the input signal level being higher than the level threshold value continues for a given time.

13 Claims, 14 Drawing Sheets



(51) **Int. Cl.**
H04R 3/02 (2006.01)
H04R 25/00 (2006.01)

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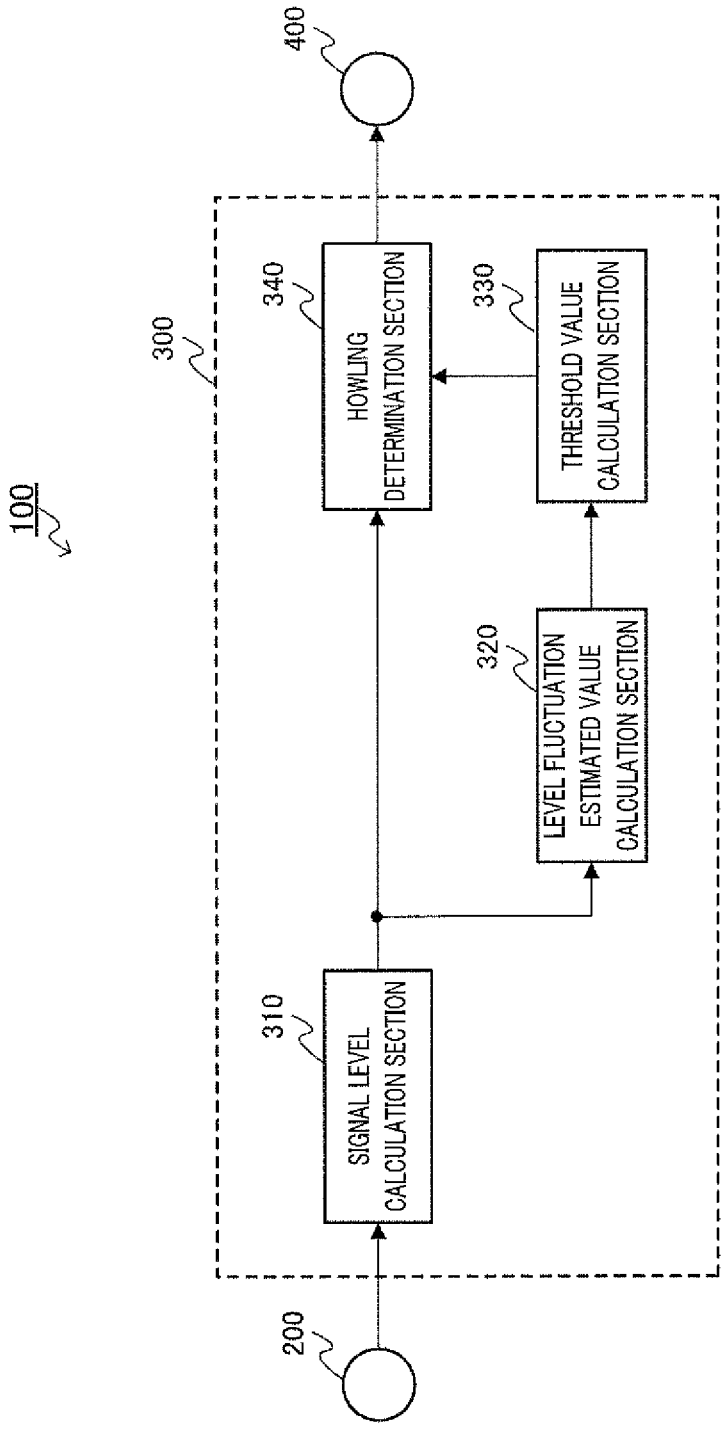

100
200
300
310
SIGNAL LEVEL CALCULATION SECTION
320
LEVEL FLUCTUATION ESTIMATED VALUE CALCULATION SECTION
330
THRESHOLD VALUE CALCULATION SECTION
340
HOWLING DETERMINATION SECTION
400

FIG. 1

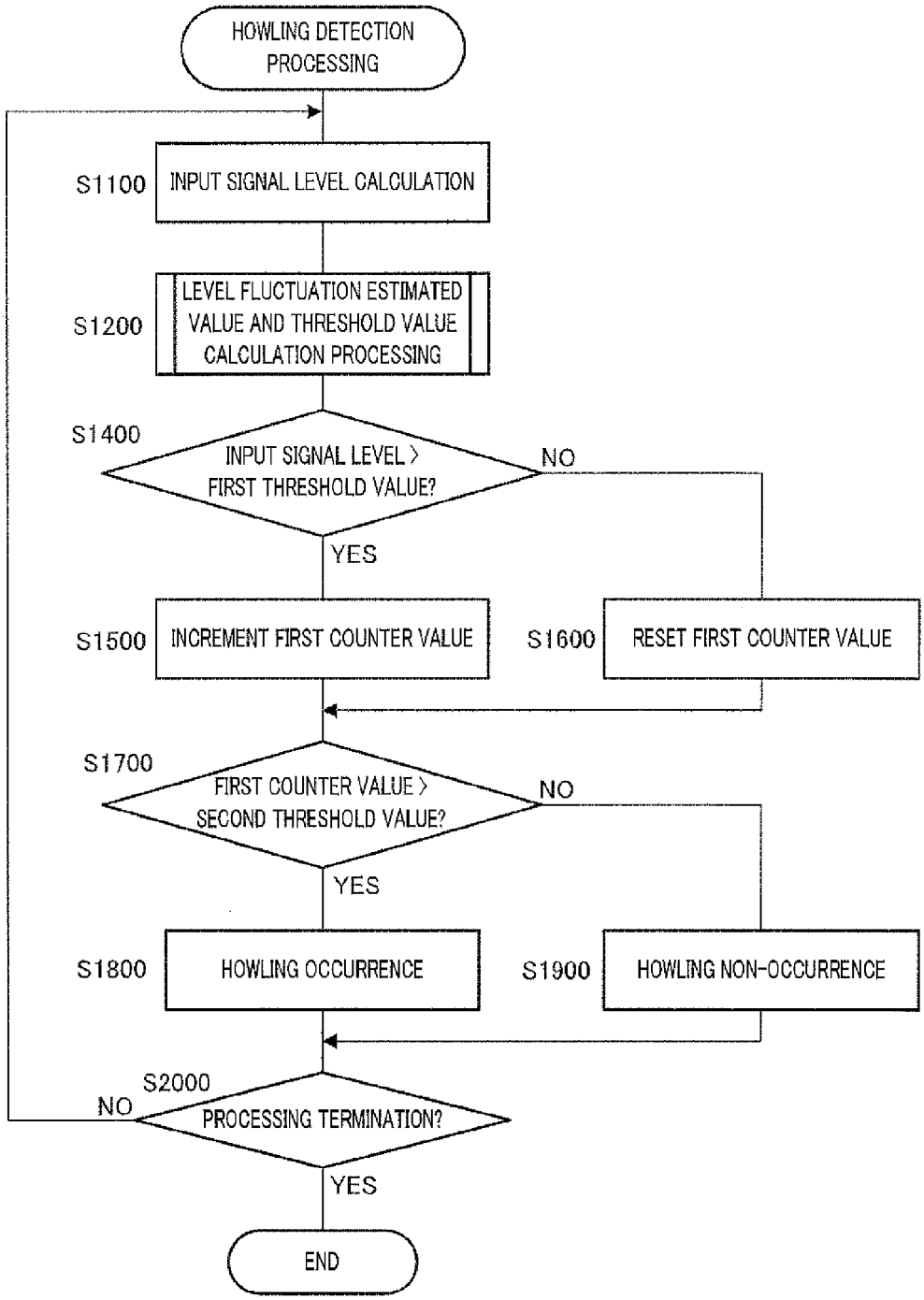

HOWLING DETECTION PROCESSING
S1100
INPUT SIGNAL LEVEL CALCULATION
S1200
LEVEL FLUCTUATION ESTIMATED VALUE AND THRESHOLD VALUE CALCULATION PROCESSING
S1400
INPUT SIGNAL LEVEL > FIRST THRESHOLD VALUE?
NO
YES
S1500
INCREMENT FIRST COUNTER VALUE
S1600
RESET FIRST COUNTER VALUE
S1700
FIRST COUNTER VALUE > SECOND THRESHOLD VALUE?
NO
YES
S1800
HOWLING OCCURRENCE
S1900
HOWLING NON-OCCURRENCE
S2000
NO
PROCESSING TERMINATION?
YES
END

FIG. 2

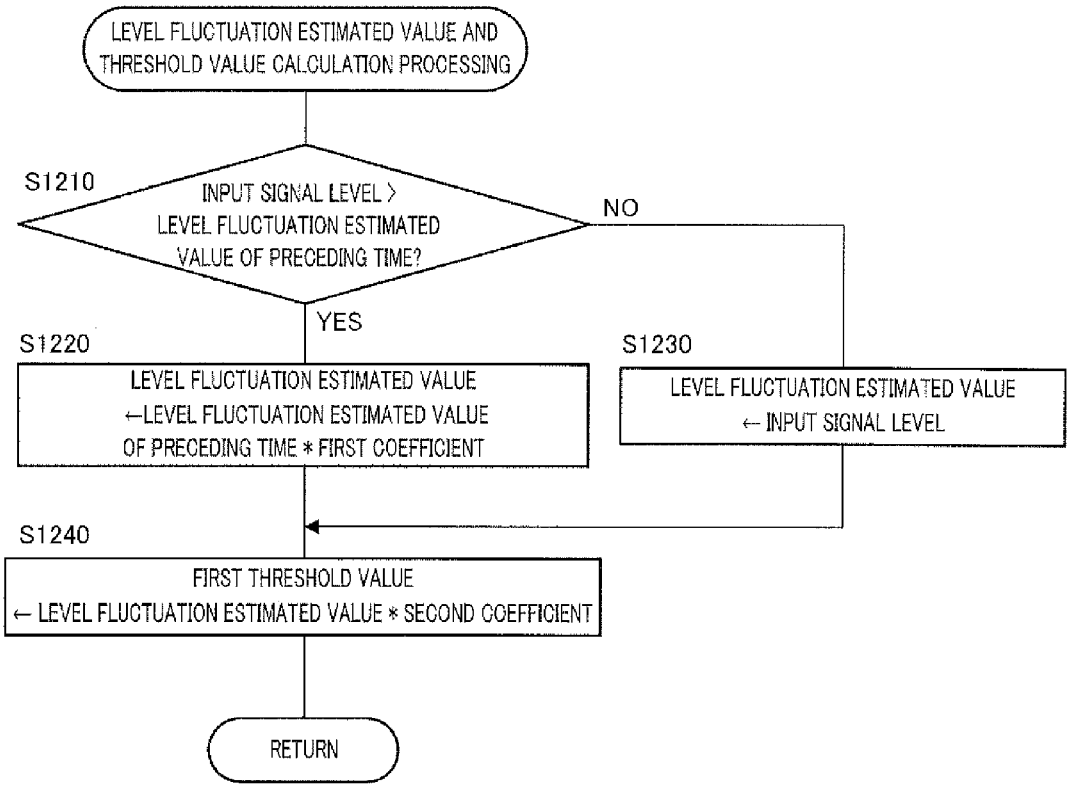

LEVEL FLUCTUATION ESTIMATED VALUE AND THRESHOLD VALUE CALCULATION PROCESSING
S1210
INPUT SIGNAL LEVEL > LEVEL FLUCTUATION ESTIMATED VALUE OF PRECEDING TIME?
NO
YES
S1220
LEVEL FLUCTUATION ESTIMATED VALUE ←LEVEL FLUCTUATION ESTIMATED VALUE OF PRECEDING TIME * FIRST COEFFICIENT
S1230
LEVEL FLUCTUATION ESTIMATED VALUE ← INPUT SIGNAL LEVEL
S1240
FIRST THRESHOLD VALUE ← LEVEL FLUCTUATION ESTIMATED VALUE * SECOND COEFFICIENT
RETURN

FIG. 3

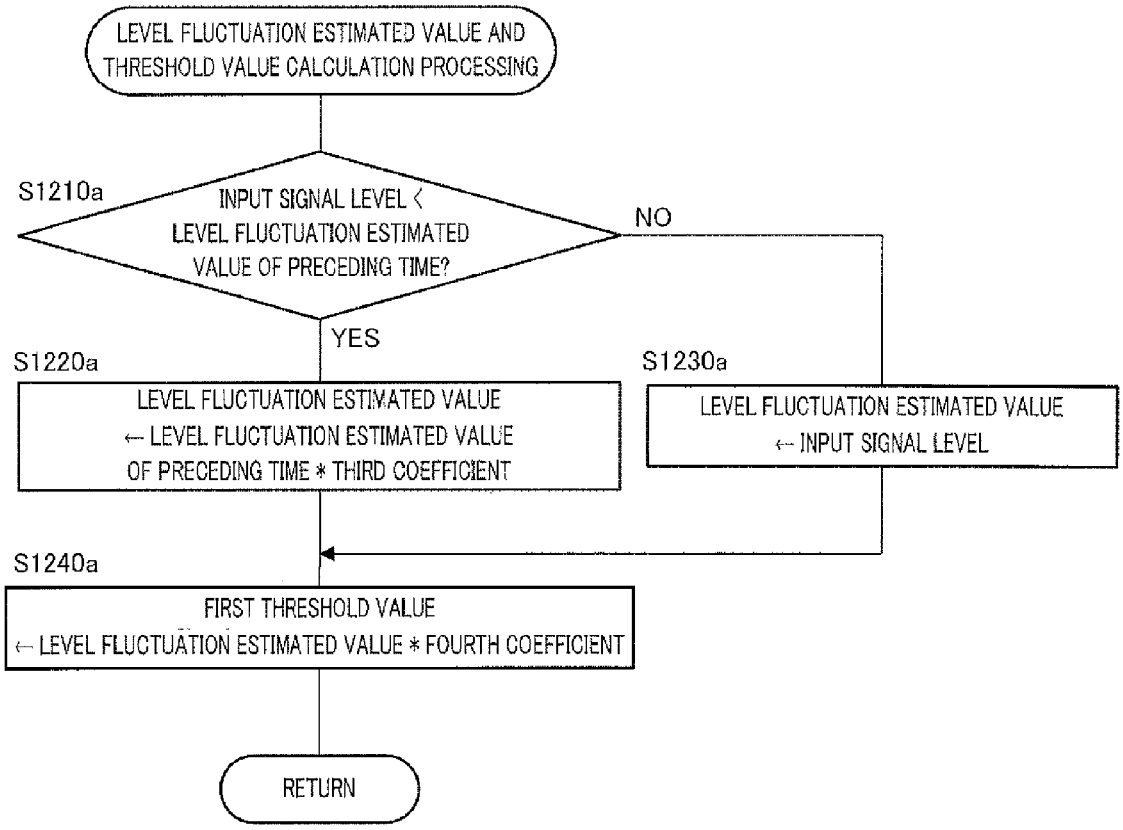

LEVEL FLUCTUATION ESTIMATED VALUE AND THRESHOLD VALUE CALCULATION PROCESSING
S1210a
INPUT SIGNAL LEVEL < LEVEL FLUCTUATION ESTIMATED VALUE OF PRECEDING TIME?
NO
YES
S1220a
LEVEL FLUCTUATION ESTIMATED VALUE ← LEVEL FLUCTUATION ESTIMATED VALUE OF PRECEDING TIME * THIRD COEFFICIENT
S1230a
LEVEL FLUCTUATION ESTIMATED VALUE ← INPUT SIGNAL LEVEL
S1240a
FIRST THRESHOLD VALUE ← LEVEL FLUCTUATION ESTIMATED VALUE * FOURTH COEFFICIENT
RETURN

FIG. 4

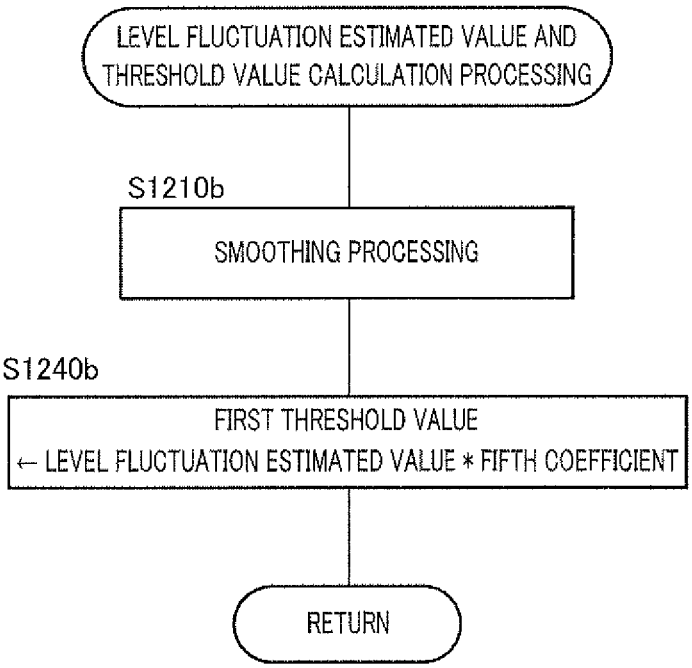

LEVEL FLUCTUATION ESTIMATED VALUE AND THRESHOLD VALUE CALCULATION PROCESSING
S1210b
SMOOTHING PROCESSING
S1240b
FIRST THRESHOLD VALUE
← LEVEL FLUCTUATION ESTIMATED VALUE * FIFTH COEFFICIENT
RETURN

FIG. 5

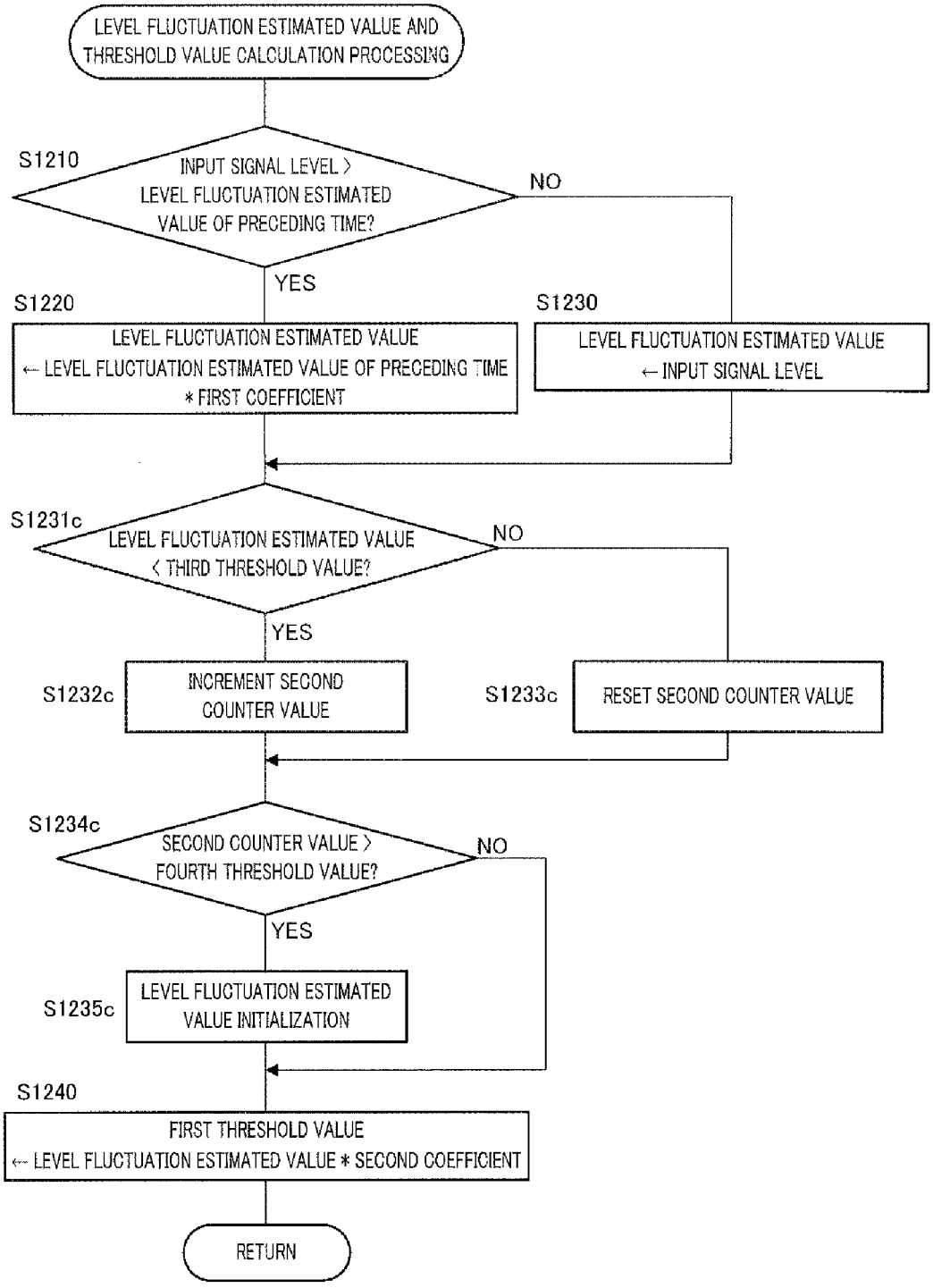

LEVEL FLUCTUATION ESTIMATED VALUE AND THRESHOLD VALUE CALCULATION PROCESSING
S1210
INPUT SIGNAL LEVEL > LEVEL FLUCTUATION ESTIMATED VALUE OF PRECEDING TIME?
NO
YES
S1220
LEVEL FLUCTUATION ESTIMATED VALUE ← LEVEL FLUCTUATION ESTIMATED VALUE OF PRECEDING TIME * FIRST COEFFICIENT
S1230
LEVEL FLUCTUATION ESTIMATED VALUE ← INPUT SIGNAL LEVEL
S1231c
LEVEL FLUCTUATION ESTIMATED VALUE < THIRD THRESHOLD VALUE?
NO
YES
S1232c
INCREMENT SECOND COUNTER VALUE
S1233c
RESET SECOND COUNTER VALUE
S1234c
SECOND COUNTER VALUE > FOURTH THRESHOLD VALUE?
NO
YES
S1235c
LEVEL FLUCTUATION ESTIMATED VALUE INITIALIZATION
S1240
FIRST THRESHOLD VALUE ← LEVEL FLUCTUATION ESTIMATED VALUE * SECOND COEFFICIENT
RETURN

FIG. 6

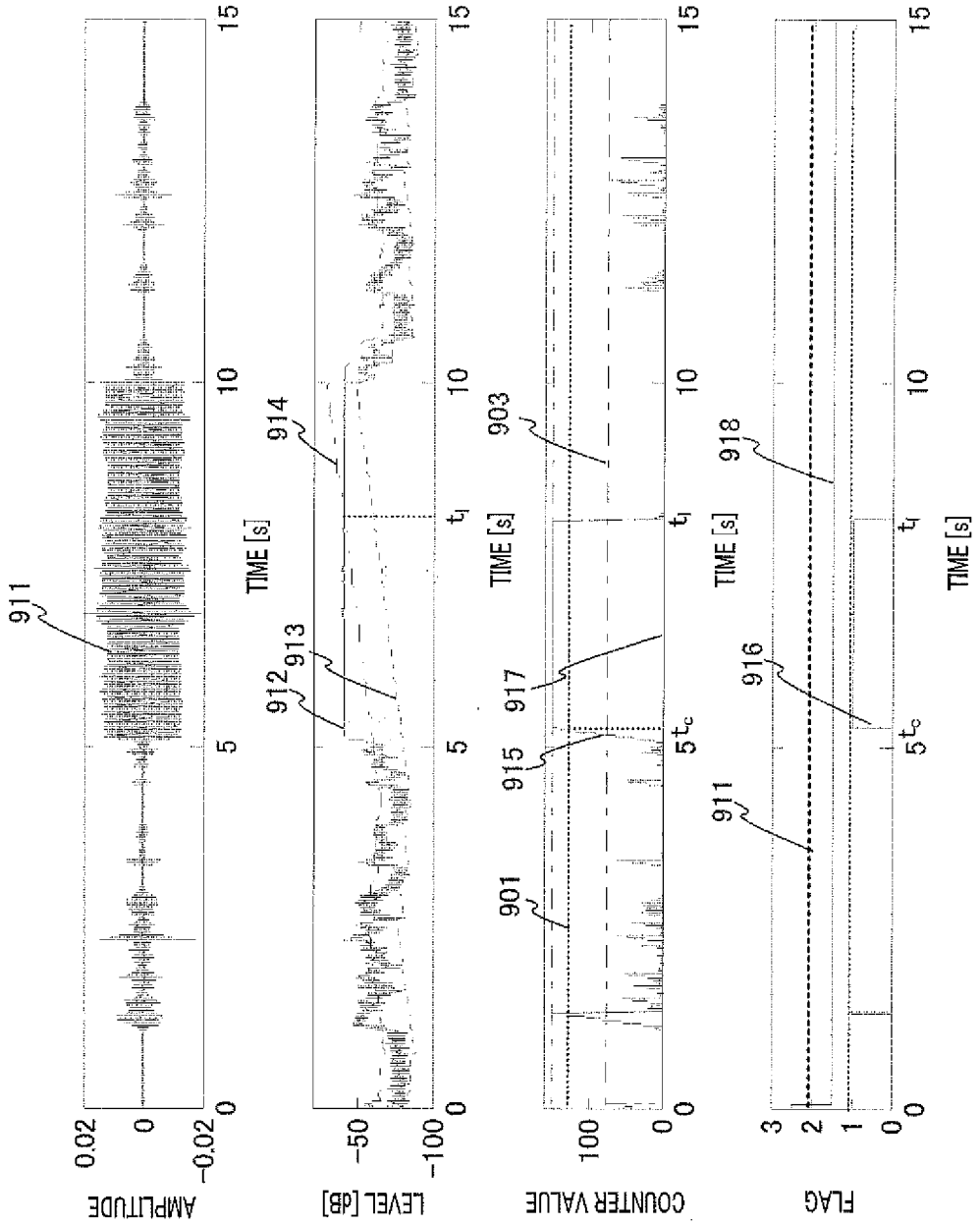
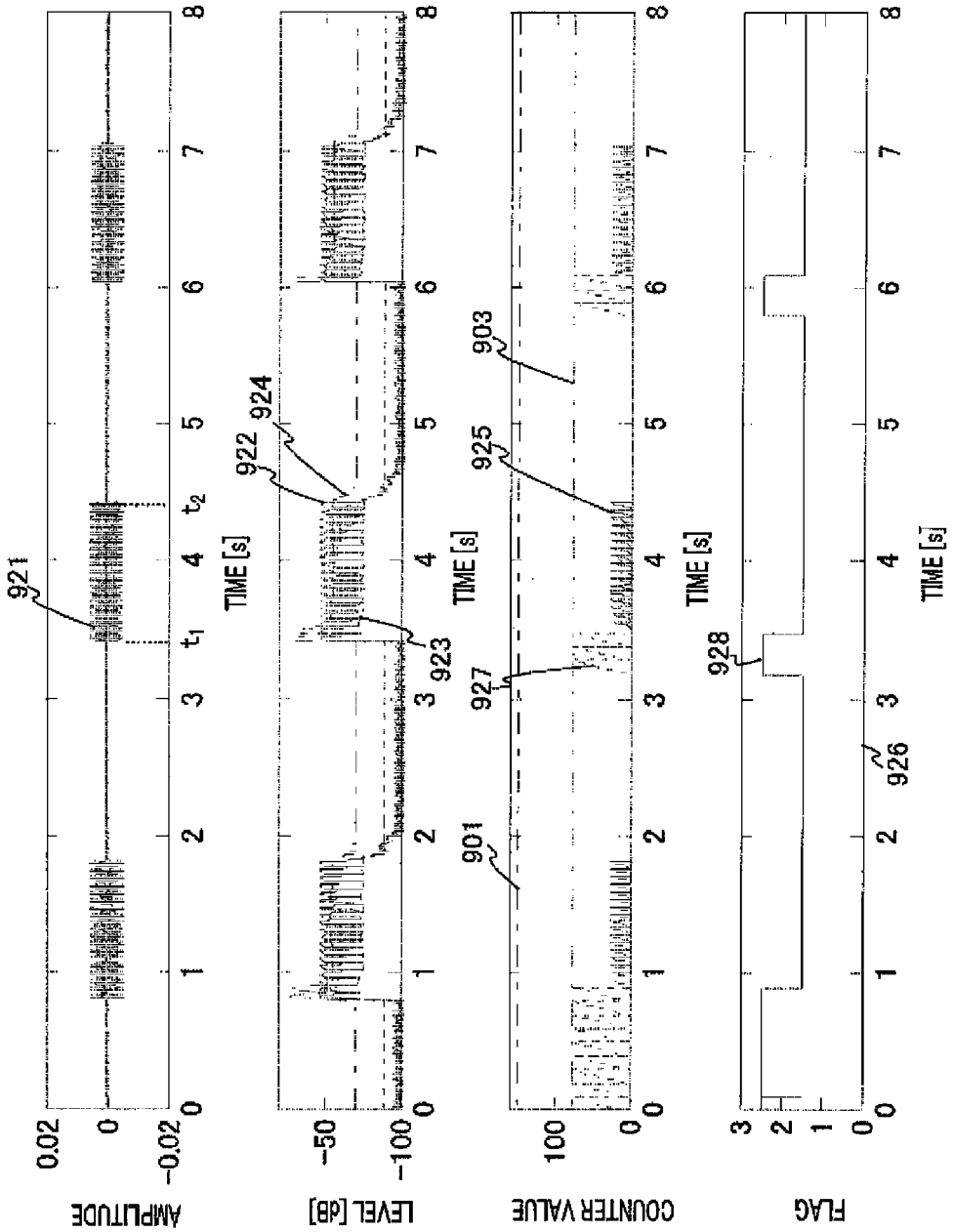


FIG. 7A

FIG. 7B

FIG. 7C

FIG. 7D


AMPLITUDE
0.02
0
−0.02
0
1
2
3
4
5
6
7
8
TIME [s]
921
t_1
t_2
FIG. 8A
LEVEL [dB]
−50
−100
922
924
923
FIG. 8B
COUNTER VALUE
100
903
925
927
901
FIG. 8C
FLAG
3
2
1
928
926
FIG. 8D

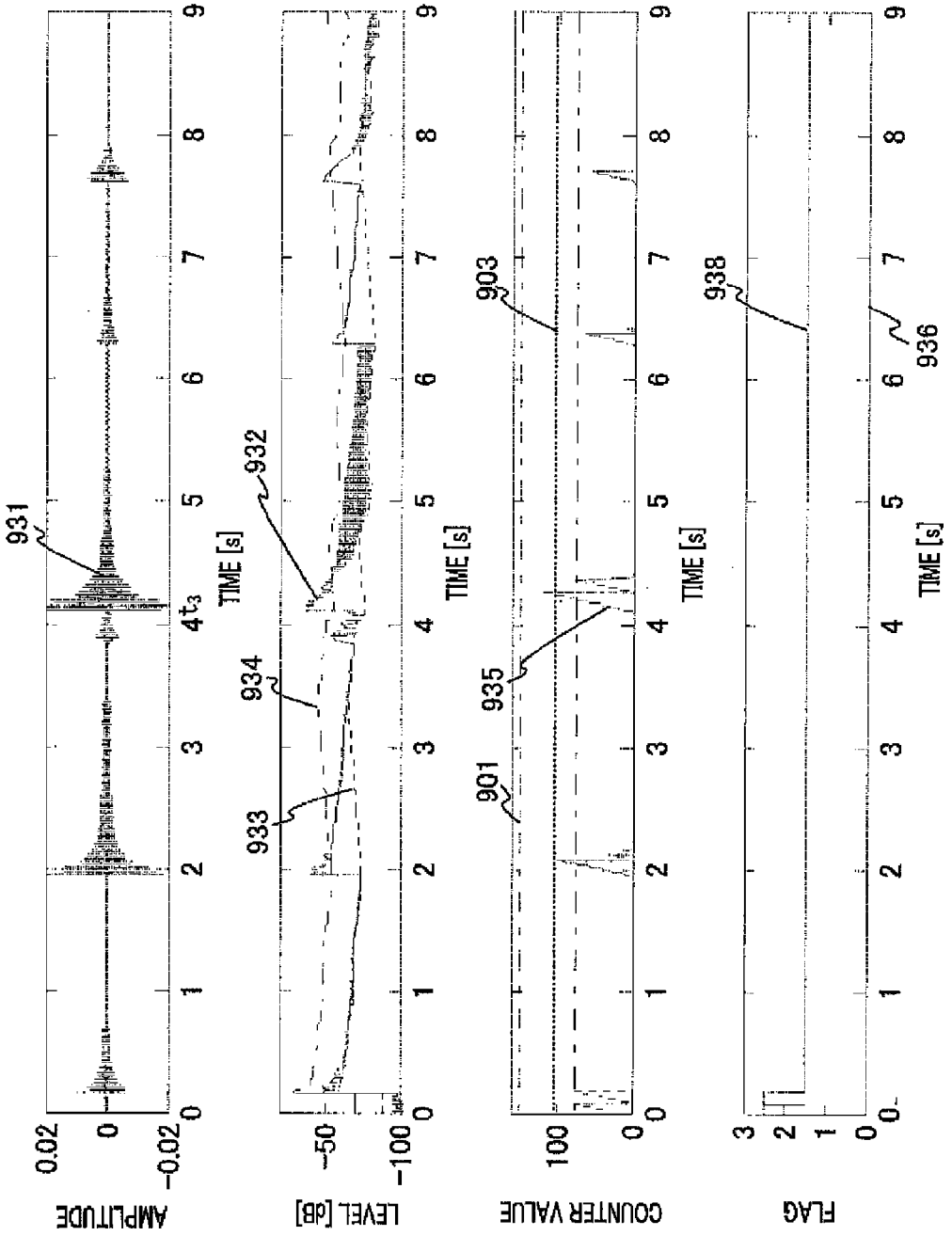


FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

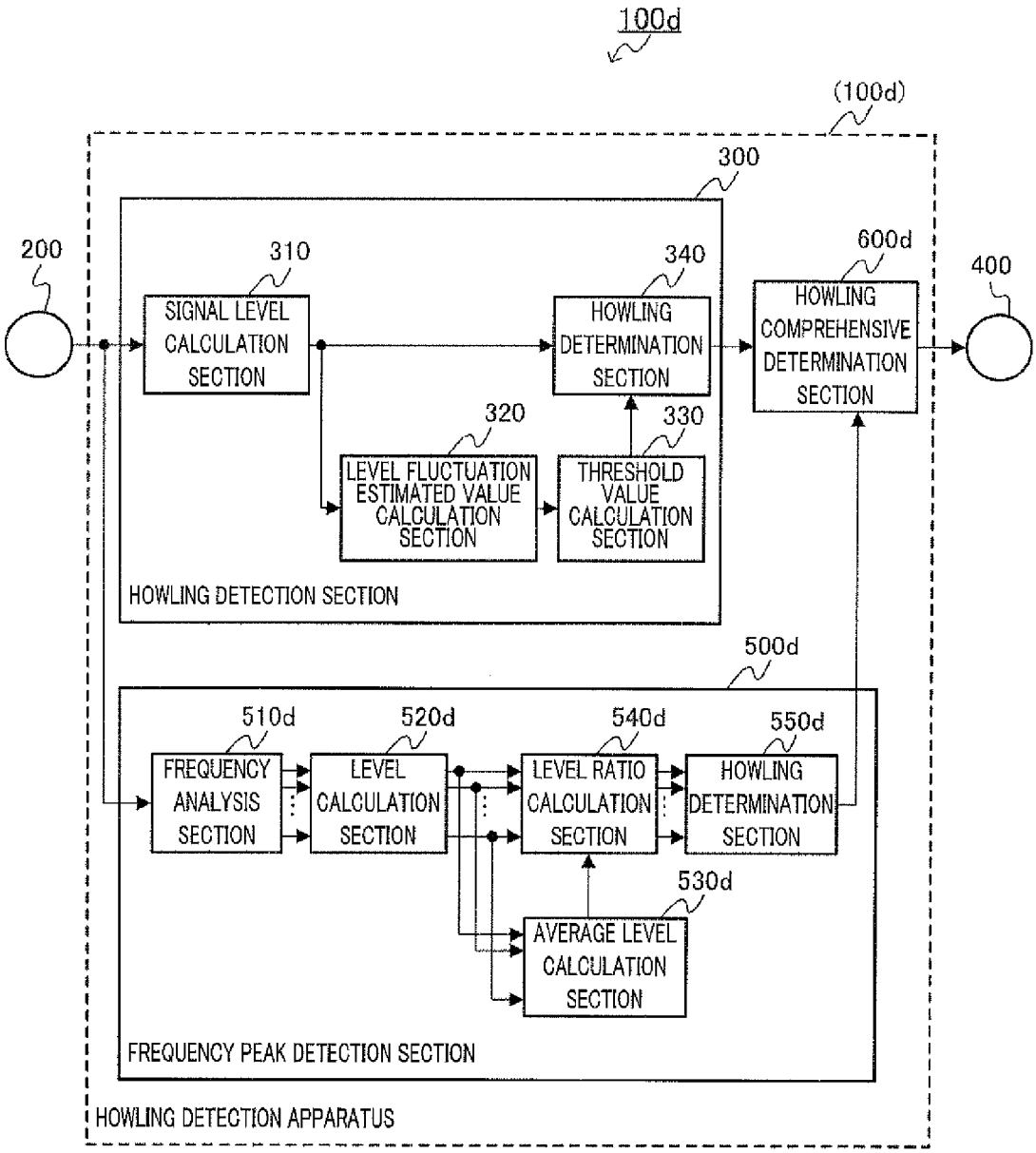

100d
(100d)
300
200
310
340
600d
400
SIGNAL LEVEL CALCULATION SECTION
HOWLING DETERMINATION SECTION
HOWLING COMPREHENSIVE DETERMINATION SECTION
320
330
LEVEL FLUCTUATION ESTIMATED VALUE CALCULATION SECTION
THRESHOLD VALUE CALCULATION SECTION
HOWLING DETECTION SECTION
500d
510d
520d
540d
550d
FREQUENCY ANALYSIS SECTION
LEVEL CALCULATION SECTION
LEVEL RATIO CALCULATION SECTION
HOWLING DETERMINATION SECTION
530d
AVERAGE LEVEL CALCULATION SECTION
FREQUENCY PEAK DETECTION SECTION
HOWLING DETECTION APPARATUS

FIG. 10

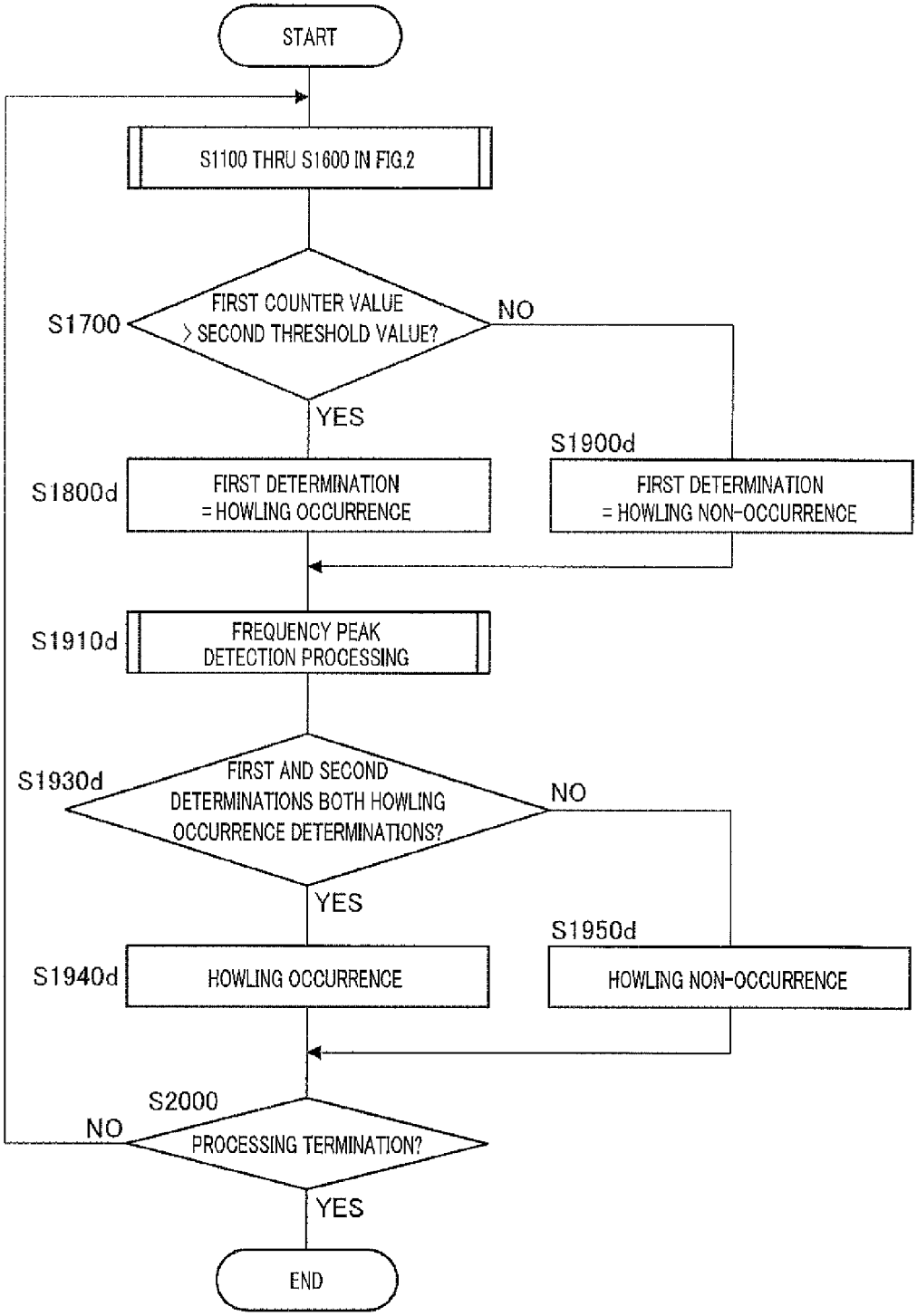

START
S1100 THRU S1600 IN FIG.2
S1700
FIRST COUNTER VALUE > SECOND THRESHOLD VALUE?
NO
YES
S1800d
FIRST DETERMINATION = HOWLING OCCURRENCE
S1900d
FIRST DETERMINATION = HOWLING NON-OCCURRENCE
S1910d
FREQUENCY PEAK DETECTION PROCESSING
S1930d
FIRST AND SECOND DETERMINATIONS BOTH HOWLING OCCURRENCE DETERMINATIONS?
NO
YES
S1940d
HOWLING OCCURRENCE
S1950d
HOWLING NON-OCCURRENCE
S2000
NO
PROCESSING TERMINATION?
YES
END

FIG. 11

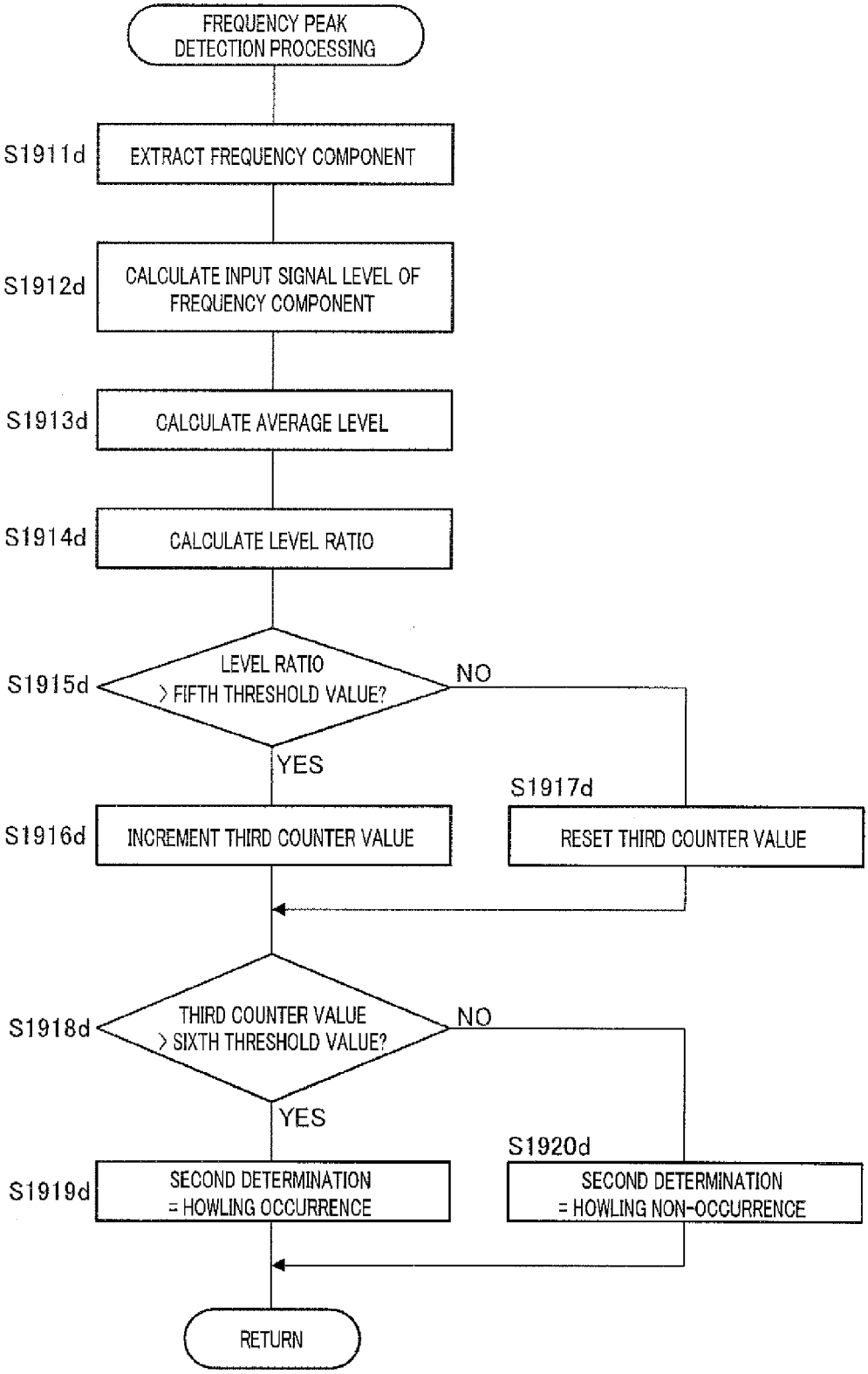

FREQUENCY PEAK DETECTION PROCESSING
S1911d
EXTRACT FREQUENCY COMPONENT
S1912d
CALCULATE INPUT SIGNAL LEVEL OF FREQUENCY COMPONENT
S1913d
CALCULATE AVERAGE LEVEL
S1914d
CALCULATE LEVEL RATIO
S1915d
LEVEL RATIO > FIFTH THRESHOLD VALUE?
NO
YES
S1916d
INCREMENT THIRD COUNTER VALUE
S1917d
RESET THIRD COUNTER VALUE
S1918d
THIRD COUNTER VALUE > SIXTH THRESHOLD VALUE?
NO
YES
S1919d
SECOND DETERMINATION = HOWLING OCCURRENCE
S1920d
SECOND DETERMINATION = HOWLING NON-OCCURRENCE
RETURN

FIG. 12

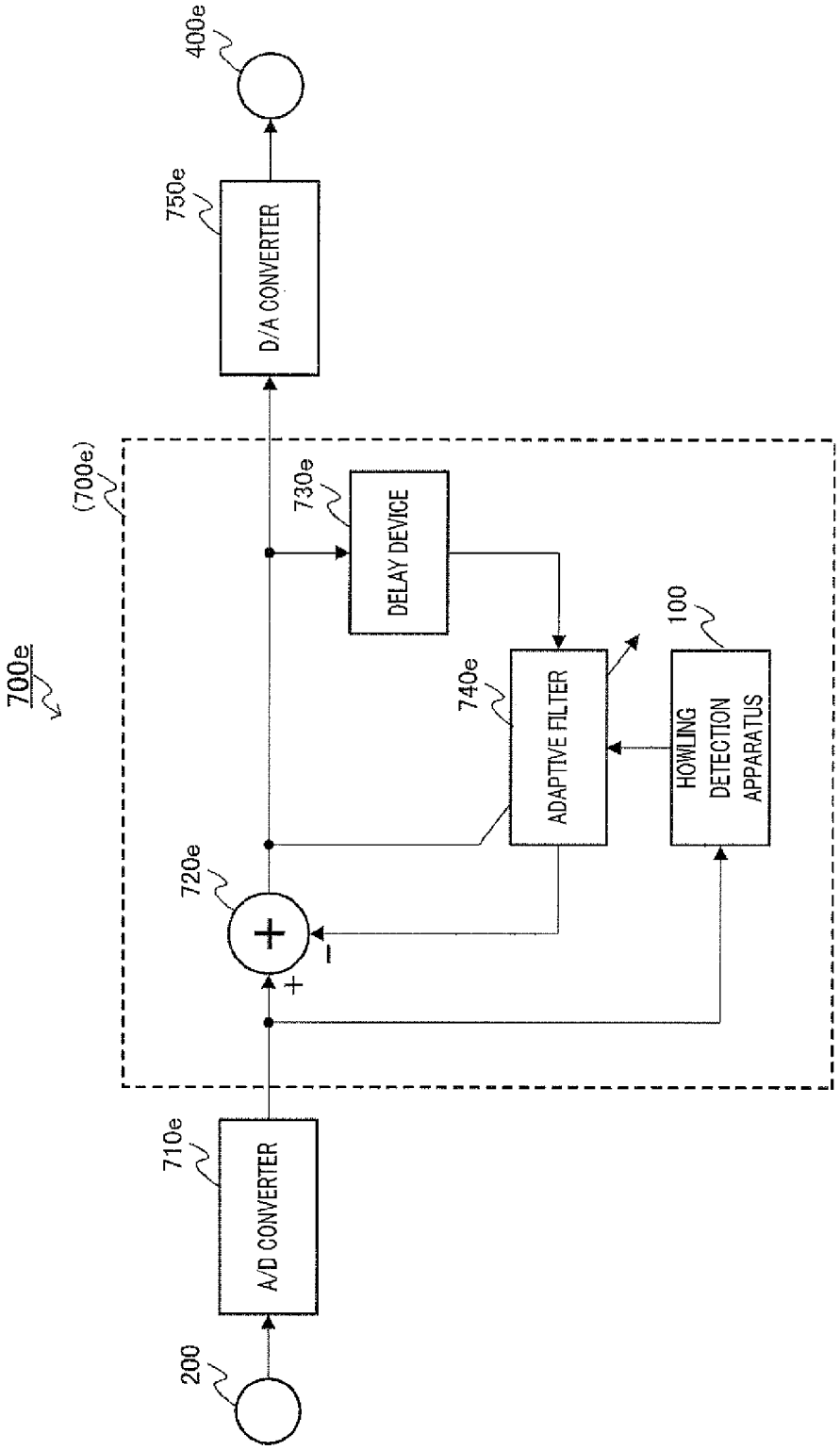

400e
750e
D/A CONVERTER
(700e)
730e
DELAY DEVICE
700e
740e
ADAPTIVE FILTER
100
HOWLING DETECTION APPARATUS
720e
+
-
+
710e
A/D CONVERTER
200

FIG. 13

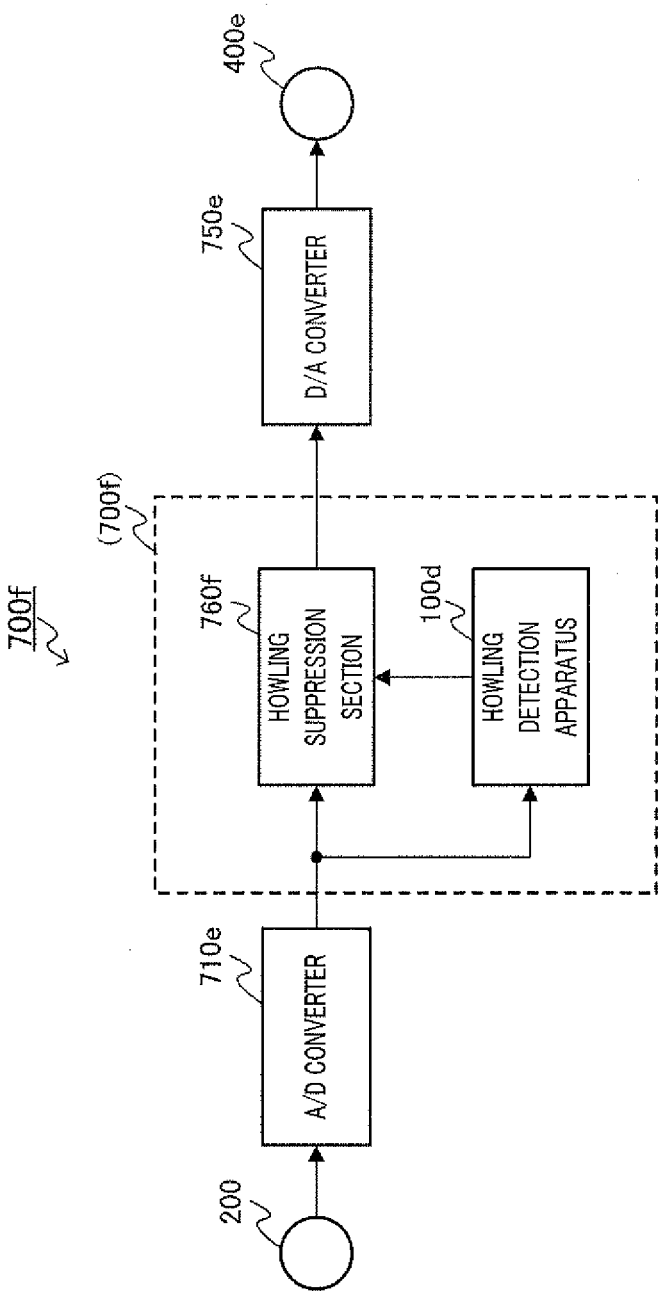

700f
(700f)
200
710e
A/D CONVERTER
760f
HOWLING SUPPRESSION SECTION
100d
HOWLING DETECTION APPARATUS
750e
D/A CONVERTER
400e

FIG. 14

HOWLING DETECTION DEVICE, HOWLING SUPPRESSING DEVICE AND METHOD OF DETECTING HOWLING

TECHNICAL FIELD

The present invention relates to a howling detection apparatus, howling suppression apparatus, and howling detection method.

BACKGROUND ART

With an acoustic apparatus that amplifies speech input from a microphone and outputs that speech from a speaker, howling occurs when speaker output sound is fed back to the microphone. This is due to the fact that acoustic coupling occurs between the speaker and the microphone, and an acoustic feedback loop is formed.

Howling is a loud continuous sound that is unpleasant for a listener, and there are consequently various kinds of technologies for suppressing howling. However, it is difficult to detect and suppress howling at high speed and with a high degree of accuracy before a listener becomes aware of the occurrence of howling.

A technology that detects howling is described in Patent Literature 1, for example. The technology described in Patent Literature 1 (hereinafter referred to as "conventional technology") calculates the signal level of an input signal from a microphone, and compares the calculated signal level with a predetermined threshold value. The conventional technology then determines that howling has occurred in the input signal, taking the continuation for a predetermined time of a state in which the signal level exceeds the threshold value as a condition. Using such technology enables howling to be suppressed.

CITATION LIST

Patent Literature

PTL 1

Patent Document 1: Japanese Patent Application Laid-Open No. HET 7-254870

SUMMARY OF INVENTION

Technical Problem

However, a problem with the conventional technology is that it may not be possible to detect howling with a high degree of accuracy, depending on the acoustic environment of the microphone. The reason for this is that when there is speech, noise, or the like in the vicinity, the signal level may exceed the threshold value even though howling has not occurred, and the occurrence of howling may be erroneously detected. Also, conversely, if a high threshold value is set in order to prevent such erroneous detection, howling may be difficult to detect.

It is an object of the present invention to detect the occurrence of howling with a high degree of accuracy.

Solution to Problem

A howling detection apparatus of the present invention has: a signal level calculation section that calculates, from an input signal, an input signal level that is the signal level of the input signal at each predetermined time; a level fluctuation estimated value calculation section that calculates a level fluctuation estimated value that is a value that gradually increases or gradually decreases by a predetermined amount from the input signal level over time; a threshold value calculation section that calculates, from the level fluctuation estimated value, a level threshold value that changes according to the level fluctuation estimated value; and a howling determination section that determines that howling has occurred in an input signal on a condition that a state in which the input signal level exceeds the level threshold value continues for a predetermined time.

A howling detection method of the present invention has: a step of calculating, from an input signal, an input signal level that is the signal level of the input signal at each predetermined time; a step of calculating a level fluctuation estimated value that is a value that gradually increases or gradually decreases by a predetermined amount from the input signal level over time; a step of calculating, from the level fluctuation estimated value, a level threshold value that changes according to the level fluctuation estimated value; and a step of determining that howling has occurred in an input signal on a condition that a state in which the input signal level exceeds the level threshold value continues for a predetermined time.

Advantageous Effects of Invention

The present invention enables the occurrence of howling to be detected with a high degree of accuracy.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram showing an example of the configuration of a howling detection apparatus according to Embodiment 1 of the present invention;

FIG. **2** is a flowchart showing an example of the operation of the howling detection apparatus according to Embodiment 1;

FIG. **3** is a flowchart showing an example of level fluctuation estimated value and threshold value calculation processing in Embodiment 1;

FIG. **4** is a flowchart showing an example of level fluctuation estimated value and threshold value calculation processing in Variant 1 of Embodiment 1;

FIG. **5** is a flowchart showing an example of level fluctuation estimated value and threshold value calculation processing in Variant 2 of Embodiment 1;

FIG. **6** is a flowchart showing an example of level fluctuation estimated value and threshold value calculation processing in Variant 3 of Embodiment 1;

FIG. **7** is a drawing showing examples of the states of signals corresponding to howling in Variant 3 of Embodiment 1;

FIG. **8** is a drawing showing examples of the states of signals corresponding to a ringtone in Variant 3 of Embodiment 1;

FIG. **9** is a drawing showing examples of the states of signals corresponding to a wind chime in Variant 3 of Embodiment 1;

FIG. **10** is a block diagram showing an example of the configuration of a howling detection apparatus according to Embodiment 2 of the present invention;

FIG. **11** is a flowchart showing an example of the operation of the howling detection apparatus according to Embodiment 2;

FIG. **12** is a flowchart showing an example of frequency peak detection processing in Embodiment 2;

FIG. **13** is a block diagram showing the configuration of a howling suppression apparatus according to Embodiment 3 of the present invention; and

FIG. **14** is a block diagram showing the configuration of a howling suppression apparatus according to Embodiment 4 of the present invention.

DESCRIPTION OF EMBODIMENTS

Now, embodiments of the present invention will be described in detail with reference to the accompanying drawings.

(Embodiment 1)

FIG. **1** is a block diagram showing an example of the configuration of a howling detection apparatus according to this embodiment.

In FIG. **1**, howling detection apparatus **100** includes input terminal **200**, signal level calculation section **310**, level fluctuation estimated value calculation section **320**, threshold value calculation section **330**, howling determination section **340**, and output terminal **400**.

Input terminal **200** is a terminal for connection to a device, such as a microphone or the like (not shown), that outputs a speech signal. Input terminal **200** inputs a speech signal output from a connected microphone, and outputs the signal to signal level calculation section **310**. Below, a speech signal input by input terminal **200** is referred to simply as an "input signal."

Signal level calculation section **310** calculates from an input signal at each predetermined time an input signal level that is the signal level of the input signal. Specifically, signal level calculation section **310** calculates an input signal level that is power or an absolute value of an input signal per unit time, and outputs to level fluctuation estimated value calculation section **320** and howling determination section **340**.

Level fluctuation estimated value calculation section **320** calculates a level fluctuation estimated value, and outputs to threshold value calculation section **330**.

Accordingly, a level fluctuation estimated value is a value that gradually increases or gradually decreases by a predetermined amount from the input signal level over time. More specifically, a level fluctuation estimated value is, for example: a value that gradually increases by a predetermined amount from a minimum input signal level value, a value that gradually decreases by a predetermined amount from a maximum input signal level value, or a value that gradually increases or gradually decreases by a predetermined amount from an average input signal level value. That is to say, a level fluctuation estimated value is a value that is sequentially updated in accordance with transitions of an input signal level, and tracks these transitions in a state in which the update amount per predetermined time (assumed to be an increment amount in this embodiment) is limited. In other words, a level fluctuation estimated value is a time-variant estimated value of an input signal level.

Accordingly, it is assumed that level fluctuation estimated value calculation section **320** treats a transition of the minimum input signal level value as an input signal level transition (input signal level fluctuation range transition). That is to say, a case is described here in which a value that gradually increases by a predetermined amount from the minimum input signal level value over time is taken as a level fluctuation estimated value.

Threshold value calculation section **330** calculates from a level fluctuation estimated value a first threshold value (level threshold value) that changes according to the level fluctuation estimated value, and outputs to howling determination section **340**. That is to say, a level fluctuation estimated value is a reference signal that is the reference for the first threshold value.

Howling determination section **340** measures the duration of a state in which the input signal level exceeds the first threshold value. Then howling determination section **340** determines that howling has occurred in the input signal, on the condition that the measured duration has reached a predetermined time threshold value. Howling determination section **340** then outputs the determination result to output terminal **400** as a howling detection result.

Output terminal **400** is a terminal of an amplifier or the like for amplifying speech input to the above microphone and outputting the speech from a speaker. Output terminal **400** outputs a howling detection result to an acoustic control apparatus having a function of suppressing howling.

Howling detection apparatus **100** is, for example, a computer that includes a CPU (central processing unit), a storage medium such as RAM (random access memory), and so forth. In this case, howling detection apparatus **100** operates by having the CPU execute a stored control program. Accordingly, this embodiment comprising a signal level calculation section **310**, level fluctuation estimated value calculation section **320**, threshold value calculation section **330**, and howling determination section **340** may be treated as howling detection section **300** incorporated in howling detection apparatus **100**.

Howling detection apparatus **100** according to this embodiment calculates a level fluctuation estimated value that is a value that gradually increases by a predetermined amount from the minimum input signal level value over time. Then howling detection apparatus **100** performs howling determination based on whether or not a state in which a threshold value that changes according to this level fluctuation estimated value is exceeded continues in excess of a predetermined time threshold value. By this means, howling detection apparatus **100** can reduce both erroneous detection and non-detection of howling irrespective of the noise level.

The reason for this is as follows. When howling occurs, it continues at the level of occurrence. Below, such an input signal level state that appears as a characteristic of howling is referred to as a "howling state," and a howling state interval is referred to as a "howling interval." Also, various kinds of sound generally present in daily activities are referred to as "noise" to distinguish them from howling, and a state in which noise is generated is referred to as a "noise state."

The above-described first threshold value makes a transition based on a level fluctuation estimated value that tracks a transition of the minimum input signal level value. The minimum input signal level value increases when noise increases. Therefore, howling determination by means of a comparison with a first threshold value according to this embodiment enables the possibility of erroneously detecting noise as howling to be reduced.

However, this kind of howling determination may increase the possibility of not detecting howling. Thus, level fluctuation estimated value calculation section **320** calculates a level fluctuation estimated value corresponding to an input signal level fluctuation range as described above. Specifically, level fluctuation estimated value calculation section **320** generates a level fluctuation estimated value that gradually increases by a predetermined amount from the minimum input signal level value over time, that is, a level fluctuation estimated value having low tracking capability with respect to an increase in the input signal level.

In a howling interval, the input signal level continues at the level of occurrence, as described above, and therefore a value

close to the maximum value is continued for a predetermined time. Thus, if the input signal level is low compared to a level fluctuation estimated value, howling detection apparatus **100** according to this embodiment replaces the level fluctuation estimated value with the input signal level value. Also, if the input signal level is high compared to a level fluctuation estimated value, howling detection apparatus **100** gradually increases the level fluctuation estimated value. This kind of level fluctuation estimated value characteristic makes it possible to set a fluctuation threshold value to be smaller than the maximum value of the input signal level fluctuation range in a howling interval, and reduces the possibility of not detecting howling.

However, with this kind of howling determination, there is a risk of noise with a high input signal level also erroneously being detected as howling. Thus, as described above, howling determination section **340** only determines howling to have occurred in an input signal when a state in which the input signal level exceeds the first threshold value continuously exceeds a predetermined time threshold value. With most noise, the input signal level is temporarily or intermittently high, and does not continue at the level of occurrence. Therefore, by performing this kind of howling determination, howling detection apparatus **100** can reduce both erroneous detection and non-detection of howling.

The operation of howling detection apparatus **100** will now be described.

FIG. **2** is a flowchart showing an example of the operation of howling detection apparatus **100**.

First, in step S**1100**, signal level calculation section **310** calculates an input signal level from an input signal. Signal level calculation section **310** performs input signal level calculation by determining the power or an absolute value of the input signal for each sample (for example, every 0.0625 [ms] at 16 [kHz] sampling) or for each frame (a plurality of samples). Therefore, howling detection apparatus **100** repeatedly performs the processing from step S**1100** to step S**2000** every predetermined sampling time.

Then, in step S**1200**, level fluctuation estimated value calculation section **320** performs level fluctuation estimated value and threshold value calculation processing. Here, level fluctuation estimated value and threshold value calculation processing is processing that calculates a level fluctuation estimated value that tracks the minimum input signal level value.

FIG. **3** is a flowchart showing an example of level fluctuation estimated value and threshold value calculation processing in step S**1200**.

In step S**1210**, level fluctuation estimated value calculation section **320** determines whether or not the input signal level calculated in the current cycle exceeds the level fluctuation estimated value calculated in the preceding cycle (hereinafter referred to simply as "the level fluctuation estimated value"). The input signal level calculated in the current cycle is hereinafter referred to simply as "the input signal level". If the input signal level exceeds the level fluctuation estimated value (S**1210**: YES), level fluctuation estimated value calculation section **320** proceeds to step S**1220**. If the input signal level does not exceed the level fluctuation estimated value, or if this is the first cycle and a level fluctuation estimated value has not yet been calculated, (S**1210**: NO), level fluctuation estimated value calculation section **320** proceeds to step S**1230**.

In step S**1220**, level fluctuation estimated value calculation section **320** updates the level fluctuation estimated value by a value obtained by multiplying the level fluctuation estimated value by a predetermined first coefficient, and proceeds to step S**1240**.

Thus, the first coefficient is a value that enables the minimum input signal level value to be traced, and that exceeds 1. In other words, the first coefficient decides the magnitude (or amount) of increase of the level fluctuation estimated value when a state in which the input signal level is large continues.

More specifically, the first coefficient is a value that tracks the level fluctuation estimated value virtually in real time for a gradual input signal level increase; for example, the sound of a train running. Furthermore, the first coefficient is a value such as to perform delayed tracking of the level fluctuation estimated value for an abrupt input signal level increase such as in the case of howling. In this embodiment, the first coefficient is assumed to be a value decided based on experimentation.

Level fluctuation estimated value calculation section **320** may also update the level fluctuation estimated value by a value obtained by adding a predetermined constant to the level fluctuation estimated value. In this case, the first coefficient is a value exceeding 0.

In step S**1230**, level fluctuation estimated value calculation section **320** updates the level fluctuation estimated value by the input signal level, and proceeds to step S**1240**.

In step S**1240**, threshold value calculation section **330** calculates a value obtained by multiplying the updated level fluctuation estimated value by a predetermined second coefficient as a first threshold value, and returns to the processing in FIG. **2**. Here, the second coefficient is a value exceeding 1. Furthermore, the second coefficient is a value such that the input signal level does not become less than or equal to the first threshold value at least at the beginning of a howling interval in tracking of an input signal level transition of the level fluctuation estimated value determined by the first coefficient.

Then, in step S**1400** in FIG. **2**, howling determination section **340** determines whether or not the input signal level exceeds the first threshold value. If the input signal level exceeds the first threshold value (S**1400**: YES), howling determination section **340** proceeds to step S**1500**. If the input signal level does not exceed the first threshold value (S**1400**: NO), howling determination section **340** proceeds to step S**1600**.

In step S**1500**, howling determination section **340** increments a first counter value and proceeds to step S**1700**.

In step S**1600**, howling determination section **340** resets the first counter value and proceeds to step S**1700**.

Since howling detection apparatus **100** repeatedly performs each processing at each predetermined sampling time in the above-described way, the first counter value indicates the length of time for which the input signal level continuously exceeds the first threshold value. For example, if the sampling time is 0.0625 [ms], a first counter value of 1600 indicates that the input signal level exceeds the first threshold value continuously for 100 [ms].

In step S**1700**, howling determination section **340** determines whether or not the first counter value exceeds a predetermined second threshold value (time threshold value).

Here, the second threshold value is a value corresponding to a time shorter than the minimum time for which the input signal level continuously exceeds the first threshold value at the beginning of a howling interval in tracking of an input signal level transition of the first threshold value determined by the first coefficient and second coefficient. Furthermore, the second threshold value is a value corresponding to a time longer than the maximum time for which an input signal level

including noise continuously exceeds the first threshold value in the above tracking. The second threshold value is, for example, a value equivalent to 0.5 second to 1 second.

In this embodiment, a combination of a first coefficient, second coefficient, and second threshold value such that howling is detected and noise is not detected is assumed to be found by performing experimentation or simulations for various noise environments.

If the first counter value exceeds the second threshold value (S**1700**: YES), howling determination section **340** proceeds to step S**1800**. If the first counter value does not exceed the second threshold value (S**1700**: NO), howling determination section **340** proceeds to step S**1900**.

In step S**1800**, howling determination section **340** determines that howling has occurred. Then howling determination section **340** outputs a determination result indicating that howling has occurred via output terminal **400**, and proceeds to step S**2000**. This is because a state in which the input signal level is high can be said to have continued for a considerable time.

In step S**1900**, howling determination section **340** determines that howling has not occurred, and proceeds directly to step S**2000**. This is because it can be said that a state in which the input signal level is high has not occurred, or has occurred but has not continued for a considerable time.

Howling determination section **340** may also output a determination result indicating that howling has not occurred via output terminal **400**. Here, it is assumed that howling determination section **340** turns on a detection flag indicating that howling is occurring each time a transition is made from a state in which howling is not occurring to a state in which howling is occurring. It is also assumed that howling determination section **340** turns off the detection flag each time a transition is made from a state in which howling is occurring to a state in which howling is not occurring.

Then, in step S**2000**, signal level calculation section **310** determines whether or not termination of howling determination processing has been directed by means of a user operation or the like. If termination of processing has not been directed (S**2000**: NO), signal level calculation section **310** returns to step S**1100** and performs processing for the next cycle. If termination of processing has been directed (S**2000**: YES), signal level calculation section **310** terminates the series of processing steps.

By means of the above-described processing, howling detection apparatus **100** can acquire a first threshold value based on the input signal of the preceding cycle, and determine the occurrence of howling based on whether or not a state in which the input signal level exceeds the threshold has continued for a predetermined time.

As described above, howling detection apparatus **100** according to this embodiment calculates a level fluctuation estimated value that is a value that gradually increases by a predetermined amount from the minimum input signal level value over time. Then howling detection apparatus **100** performs howling determination based on whether or not a state in which a threshold value that changes according to the calculated level fluctuation estimated value is exceeded continues in excess of a predetermined time threshold value. By this means, howling detection apparatus **100** can reduce both erroneous detection and non-detection of howling irrespective of the noise level.

As stated above, a conventional apparatus performs threshold value determination using a predetermined threshold value, and its determination of howling occurrence is level-dependent. Consequently, in order to perform determination in a stable fashion in a noise environment using this conventional apparatus, it is necessary to perform point-by-point threshold value adjustment in line with the acoustic environment so as to detect only howling with a high degree of accuracy.

In contrast, howling detection apparatus **100** according to this embodiment can reduce both erroneous detection and non-detection of howling without performing point-by-point adjustment of a threshold value used for howling detection. Therefore, howling detection apparatus **100** according to this embodiment can detect howling in a stable fashion even in a noise environment, and can detect the occurrence of howling with a higher degree of accuracy than in the case of conventional technology.

A value treated as information representing a range of input signal level fluctuation is not limited to the minimum input signal level value. As a variant of Embodiment 1, a description is given below of level fluctuation estimated value and threshold value calculation processing when a level fluctuation estimated value is found from a transition of a value other than the minimum input signal level value.

(Variant 1 of Embodiment 1)

Variant 1 of Embodiment 1 is an example of a case in which a level fluctuation estimated value is found from a transition of the maximum input signal level value. That is to say, this variant is an example in which a value that gradually decreases by a predetermined amount from the maximum input signal level value over time is calculated as a level fluctuation estimated value.

FIG. **4** is a flowchart showing an example of level fluctuation estimated value and threshold value calculation processing in this variant, and corresponds to FIG. **3**,

When an input signal level is input (step S**1100** in FIG. **2**), level fluctuation estimated value calculation section **320** proceeds to step S**1210***a*.

In step S**1210***a*, level fluctuation estimated value calculation section **320** determines whether or not the input signal level is less than the level fluctuation estimated value. If the input signal level is less than the level fluctuation estimated value (S**1210***a*: YES), level fluctuation estimated value calculation section **320** proceeds to step S**1220***a*. If the input signal level is not less than the level fluctuation estimated value, or if this is the first cycle and a level fluctuation estimated value has not yet been calculated (that is, S**1210***a*: NO), level fluctuation estimated value calculation section **320** proceeds to step S**1230***a*.

In step S**1220***a*, level fluctuation estimated value calculation section **320** updates the level fluctuation estimated value by a value obtained by multiplying the level fluctuation estimated value by a predetermined third coefficient, and returns to the processing in FIG. **2**. Here, the third coefficient is a value that tracks the level fluctuation estimated value virtually in real time for a gradual decrease in the input signal level of howling, and performs delayed tracking of attenuation of the input signal level such as a fall section of train noise.

Level fluctuation estimated value calculation section **320** may also update the level fluctuation estimated value by a value obtained by subtracting a predetermined constant from the level fluctuation estimated value. In this case, the third coefficient is a value exceeding 0.

In step S**1230***a*, level fluctuation estimated value calculation section **320** updates the level fluctuation estimated value by the input signal level, and proceeds to step S**1240***a*.

In step S**1240***a*, threshold value calculation section **330** calculates a value obtained by multiplying the updated level fluctuation estimated value by a predetermined fourth coefficient as a first threshold value, and returns to the processing in FIG. **2**. Here, the fourth coefficient is a value exceeding 0 and

less than 1. Furthermore, the fourth coefficient is a value such that the input signal level does not become greater than or equal to the first threshold value at least immediately after a howling interval in tracking of an input signal level transition of the level fluctuation estimated value determined by the third coefficient.

Also, the second threshold value used in step S**1700** is a value enabling a distinction to be made between howling and noise by tracking an input signal level transition of the first threshold value as determined by the first coefficient and third coefficient.

In this way, howling detection apparatus **100** can calculate a first threshold value such as to perform delayed tracking of an input signal level transition based on the maximum input signal level value.

In particular, howling detection apparatus **100** calculates a first threshold value such as to perform delayed tracking of a decrease in the input signal level. By this means, howling detection apparatus **100** can prevent erroneous detection of the occurrence of howling in gradual attenuation of the input signal level such as in a fall section of train noise. That is to say, howling detection apparatus **100** can sequentially calculate detection threshold values according to input signal level envelope information (magnitude and temporal transition) from continuation at the level at which howling occurred.

By this means, howling detection apparatus **100** can reduce both erroneous detection and non-detection of howling without performing point-by-point adjustment of a threshold value used for howling detection.

(Variant 2 of Embodiment 1)

Variant 2 of Embodiment 1 is an example of a case in which a transition of the long-term average value of an input signal level is treated as an input signal level transition. That is to say, this variant is an example in which a value that gradually increases or gradually decreases by a predetermined amount from an average input signal level value over time is calculated as a level fluctuation estimated value.

FIG. **5** is a flowchart showing an example of level fluctuation estimated value and threshold value calculation processing in this variant, and corresponds to FIG. **3**.

When an input signal level is input (step S**1100** in FIG. **2**), level fluctuation estimated value calculation section **320** proceeds to step S**1210***b*.

In step S**1210***b*, level fluctuation estimated value calculation section **320** performs smoothing processing on time series data of the input signal level. Then level fluctuation estimated value calculation section **320** updates the level fluctuation estimated value by a value obtained by the smoothing processing. The value obtained by the smoothing processing is a long-term average value of the input signal level. If sufficient cycles have not yet elapsed for a long-term average value to be calculated, level fluctuation estimated value calculation section **320** may set a predetermined initial value as the level fluctuation estimated value.

Level fluctuation estimated value N(k) for current cycle k after smoothing can be found, for example, by performing the moving average calculation shown in equation 1 below.

[1]

$$N(k)=(1-\alpha)\times X(k)+\alpha\times N(k-1) \quad \text{(Equation 1)}$$

Here, X(k) is the input signal level in current cycle k, N(k−1) is the level fluctuation estimated value for preceding cycle k−1, and α is a value of an order enabling the average input signal level value to be traced, being a forgetting factor that satisfies the relationship $0<<\alpha<1$. More specifically, α is a value that tracks the level fluctuation estimated value virtually in real time for an input signal level change of a gradual update amount such as in the case of the noise of a train. That is to say, α is a value such as to perform delayed tracking of an input signal level change by an abrupt update amount of howling.

Then, in step S**1240***b*, threshold value calculation section **330** calculates a value obtained by multiplying the updated level fluctuation estimated value by a predetermined fifth coefficient as a first threshold value, and returns to the processing in FIG. **2**.

Here, the fifth coefficient is a value such that the input signal level does not become less than or equal to the first threshold value at least at the beginning of a howling interval in tracking an input signal level transition of the level fluctuation estimated value as determined by forgetting function α. The fifth coefficient is, for example, 1, in which case threshold value calculation section **330** uses the level fluctuation estimated value directly as the first coefficient.

Threshold value calculation section **330** may also use, as the first threshold, a value obtained by multiplying the level fluctuation estimated value by a value greater than or equal to 1 as the fifth coefficient, or a value obtained by adding a predetermined constant greater than or equal to 0 to the level fluctuation estimated value, as the first threshold value.

In this way, howling detection apparatus **100** can calculate a first threshold value such as to perform delayed tracking of an input signal level transition based on a long-term average value of the input signal level.

(Variant 3 of Embodiment 1)

Variant 3 of Embodiment 1 is an example of a case in which a level fluctuation estimated value is tracked virtually in real time for a rise of the input signal level at the start of noise.

FIG. **6** is a flowchart showing an example of level fluctuation estimated value and threshold value calculation processing in this variant, and corresponds to FIG. **3**.

After updating the level fluctuation estimated value (steps S**1210** through S**1230**), howling detection apparatus **100** proceeds to step S**1231***c*.

In step S**1231***c*, when inputting a signal level (step S**1100** in FIG. **2**), level fluctuation estimated value calculation section **320** determines whether or not the level fluctuation estimated value is less than a predetermined third threshold value.

Here, the third threshold value is a value greater than or equal to 0, and is, for example, a value equivalent to the noise level in a quiet acoustic environment.

If the level fluctuation estimated value is less than the third threshold value (S**1231***c*: YES), level fluctuation estimated value calculation section **320** proceeds to step S**1232***c*. If the level fluctuation estimated value is not less than the third threshold value, or if this is the first cycle and a level fluctuation estimated value has not yet been calculated, (S**1231***c*: NO), level fluctuation estimated value calculation section **320** proceeds to step S**1233***c*.

In step S**1232***c*, level fluctuation estimated value calculation section **320** increments a second counter value and proceeds to step S**1234***c*.

In step S**1233***c*, level fluctuation estimated value calculation section **320** resets the second counter value and proceeds to step S**1234***c*.

That is to say, the second counter value is a value indicating the duration of a state in which the level fluctuation estimated value does not exceed the third threshold value.

Then, in step S**1234***c*, level fluctuation estimated value calculation section **320** determines whether or not the second counter value exceeds a predetermined fourth threshold value.

Here, the fourth threshold value is, for example, a value equivalent to 0.1 second to 0.5 second, and is a value set in

order to determine whether a substantially silent state is continuing in which the noise level is low and there is no input signal to the microphone.

If the second counter value exceeds the fourth threshold value (S1234*c*: YES), level fluctuation estimated value calculation section **320** proceeds to step S1235*c*. If the second counter value does not exceed the fourth threshold value (S1234*c*: NO), level fluctuation estimated value calculation section **320** proceeds directly to step S1240, and thereby returns to the processing in FIG. **2**.

In step S1235*c*, level fluctuation estimated value calculation section **320** initializes the level fluctuation estimated value—that is, makes the level fluctuation estimated value the same as the input signal level—and then proceeds to step S1240 and returns to the processing in FIG. **2**.

That is to say, when a state in which the level fluctuation estimated value does not exceed the third threshold value continues in excess of a predetermined time threshold value, a state is established in which the input signal level is tracked for a predetermined time. This is because, when the input signal level changes abruptly from a low state to a high state, there is a possibility of howling being erroneously determined to have occurred if the level fluctuation estimated value that is the basis of the first threshold value does not track this.

By means of this kind of level fluctuation estimated value and threshold value calculation processing, howling detection apparatus **100** can track the level fluctuation estimated value virtually in real time at a rise of the input signal level, and then perform delayed tracking.

By this means, howling detection apparatus **100** can prevent noise for which the input signal level increases abruptly at the start, as in the case of a telephone ringtone, from being erroneously detected as howling, while allowing howling to be detected. Therefore, howling detection apparatus **100** can further improve the accuracy of howling detection.

The ability of howling detection apparatus **100** according to Variant 3 to detect the occurrence of howling with a high degree of accuracy will now be explained.

Here, a first input signal in which howling is included, a second input signal in which a telephone ringtone is included, and a third input signal in which the sound of a wind chime is included, are assumed.

FIG. **7** is a drawing showing examples of the states of signals in the case of a first input signal in which howling is included. FIG. **7**A shows temporal transitions of the input signal. FIG. **7**B shows temporal transitions of the input signal level, the level fluctuation estimated value, and the first threshold value. FIG. **7**C shows temporal transitions of the first counter value. FIG. **7**D shows temporal transitions of the detection flag and an initialization flag. Here, the initialization flag is for indicating whether or not there is a state in which the level fluctuation estimated value is to be initialized.

In first input signal **911**, the interval from the fifth second to the tenth second is a howling interval. As shown in FIG. **7**A, the amplitude of first input signal **911** is large in the howling interval. Therefore, as shown in FIG. **7**B, input signal level **912** maintains a high-level state in the howling interval (S1210: YES).

Also, as shown in FIG. **7**B, in the howling interval, level fluctuation estimated value **913** gradually increases (S1220) and first threshold value **914** also gradually increases (S1240).

In the interval up to time t_1 at which first threshold value **914** reaches input signal level **912**, input signal level **912** is continuously determined to exceed first threshold value **914** (S1400: YES). As a result, first counter value **915** gradually increases (S1500).

Then, as shown in FIG. **7**C, when first counter value **915** exceeds second threshold value **901** at time t_c before time t_1 (S1700: YES), detection flag **916** is turned on (S1800) as shown in FIG. **7**D. Also, when time t_1 at which first threshold value **914** reaches input signal level **912** is passed (S1400: NO), first counter value **915** is reset and becomes less than or equal to second threshold value **901** (S1600, 1700: NO).

As a result, detection flag **916** is turned off (S1900) as shown in FIG. **7**D.

In this example, it is assumed that level fluctuation estimated value **913** does not become continuously less than the third threshold value (S1231*c*: NO). In this case, as shown in FIG. **7**C, second counter value **917** does not increase (S1231*c*) and does not exceed fourth threshold value **903** (S1234*c*: NO).

As a result, initialization flag **918** remains in the off state as shown in FIG. **7**D.

FIG. **8** is a drawing showing examples of the states of signals in the case of a second input signal in which a telephone ringtone is included but howling is not included, and corresponds to FIG. **7**.

In second input signal **921**, the interval from time t_1 to time t_2 is an interval in which a telephone ringtone sounds (hereinafter referred to as "a ringtone interval").

As shown in FIG. **8**A, since a telephone ringtone is not a continuous sound, the amplitude of second input signal **921** repeatedly alternates between a large state and a small state in short cycles in a ringtone interval. Therefore, as shown in FIG. **8**B, in a ringtone interval, determination that input signal level **922** exceeds first threshold value **924** and determination that input signal level **922** does not exceed first threshold value **924** repeatedly alternate in short cycles (S1400: NO).

As a result, as shown in FIG. **8**C, first counter value **925** does not increase (S1600) and does not exceed second threshold value **901** (S1700: NO).

However, in an interval until level fluctuation estimated value **923** tracks a rise of input signal level **922** accompanying a rise of second input signal **921** at time t_1, input signal level **922** enters a state that exceeds level fluctuation estimated value **923**. Therefore, if level fluctuation estimated value **923** tracking of a rise of input signal level **922** is delayed, there is a risk of erroneous detection as an occurrence of howling.

Thus, by means of the above-described initialization, initialization flag **928** goes to the on state until time t_1 of a rise of input signal level **922** as shown in FIG. **8**D. That is to say, level fluctuation estimated value **923** and first threshold value **924** rapidly track a rise of input signal level **922** as shown in FIG. **8**B.

Following this, initialization flag **928** goes to the off state since a state in which level fluctuation estimated value **923** is less than the third threshold value does not continue. That is to say, level fluctuation estimated value **923** performs delayed tracking of the abrupt increase in the input signal level.

Therefore, as shown in FIG. **8**D, detection flag **926** is always turned off (S1900), including at the time of a rise of second input signal **921**.

Thus, a noise for which the input signal level increases intermittently, as in the case of a telephone ringtone, is not erroneously detected as howling by howling detection apparatus **100** according to this embodiment.

FIG. **9** is a drawing showing examples of the states of signals in the case of a third input signal in which the sound of a wind chime is included but howling is not included, and corresponds to FIG. **7**.

It is assumed that an interval in which a wind chime sounds is continuous in third input signal **931**. As shown in FIG. **9**A, the amplitude of third input signal **931** is large at time t_3 when

the sound of the wind chime begins, but rapidly attenuates, and, as shown in FIG. **9**B, input signal level **932** also makes a transition to a low state within a short time (S**1210**: NO).

That is to say, as shown in FIG. **9**B, even if level fluctuation estimated value **933** exceeds first threshold value **934** calculated based on level fluctuation estimated value **933** (S**1400**: YES) immediately after time t_3, it immediately becomes less than or equal to first threshold value **934** (S**1400**: NO). Therefore, as shown in FIG. **9**C, even if first counter value **935** increases (S**1500**) immediately after time t_3, it is immediately reset (S**1600**).

As a result, first counter value **935** does not reach second threshold value **901** (S**1700**: NO), and detection flag **936** remains in the off state as shown in FIG. **9**D.

In this example, it is assumed that level fluctuation estimated value **933** does not become continuously less than the third threshold value (S**1231***c*: NO). In this case, as shown in FIG. **9**C, second counter value **937** does not increase (S**1233***c*) and does not exceed fourth threshold value **903** (S**1234***c*: NO). As a result, initialization flag **938** remains in the off state as shown in FIG. **9**D.

Thus, a noise for which the input signal level rapidly attenuates, as in the case of the sound of a wind chime, is not erroneously detected as howling by howling detection apparatus **100** according to this embodiment.

(Embodiment 2)

Embodiment 2 of the present invention is a howling detection apparatus in which the accuracy of howling detection is improved using a frequency peak of an input signal.

FIG. **10** is a block diagram showing an example of the configuration of a howling detection apparatus according to this embodiment, and corresponds to FIG. **1** of Embodiment 1. Parts in FIG. **10** identical to those in FIG. **1** are assigned the same reference signs as in FIG. **1**, and descriptions thereof are omitted here.

In FIG. **10**, howling detection apparatus **100***d* according to this embodiment includes input terminal **200**, howling detection section **300** of Embodiment 1, frequency peak detection section **500***d*, howling comprehensive determination section **600***d*, and output terminal **400**.

In this embodiment, input terminal **200** outputs an input signal not only to howling detection section **300** but also to frequency peak detection section **500***d*. Also, howling detection section **300** outputs a howling determination result not to output terminal **400** but to howling comprehensive determination section **600***d* as a first determination result.

Frequency peak detection section **500***d* determines whether or not howling has occurred in an input signal based on the presence or absence of a frequency peak in the input signal. Frequency peak detection section **500***d* includes frequency analysis section **510***d*, level calculation section **520***d*, average level calculation section **530***d*, level ratio calculation section **540***d*, and howling determination section **550***d*

Frequency analysis section **510***d* converts or divides an input signal into frequency components for each of a plurality of band divisions into which the frequency band is divided, and outputs frequency components of each band division (hereinafter referred to simply as "frequency components") to level calculation section **520***d*.

Various known methods of converting or dividing a temporal signal into a plurality of frequency components can be used as the method of conversion or division of an input signal into frequency components. Known methods include, for example, a fast Fourier transform, a filter bank composed of a plurality of FIR (finite impulse response) or IIR (infinite impulse response) filters, or the like.

Level calculation section **520***d* calculates a per-unit-time power value or absolute value for each converted or divided frequency component. Level calculation section **520***d* outputs calculated, on a per-frequency-component basis, input signal levels to average level calculation section **530***d* and level ratio calculation section **540***d*.

Average level calculation section **530***d* calculates an average value of the input levels of the plurality of frequency components, and outputs the calculated average value to level ratio calculation section **540***d* as an average level.

Level ratio calculation section **540***d* calculates a ratio with respect to the average value (hereinafter referred to as "level ratio") for each input signal level of the plurality of frequency components, and outputs the calculated per-frequency-component level ratios to howling determination section **550***d*.

Howling determination section **550***d* determines whether or not howling has occurred in the input signal based on the level ratio of each frequency component, and outputs a second determination result to howling comprehensive determination section **600***d* as a howling detection result.

By accepting input that indicates both the first determination result and second determination result conclude that howling has occurred as a condition, howling comprehensive determination section **600***d* outputs a final determination result indicating that howling has occurred.

Howling detection apparatus **100***d* of this kind can improve the accuracy of howling detection since it uses a result combining a determination result from howling detection section **300** and a determination result from frequency peak detection section **500***d* as a final determination result.

Howling detection apparatus **100***d* may also have a configuration in which input terminal **200** and output terminal **400** are omitted.

The operation of howling detection apparatus **100***d* will now be described.

FIG. **11** is a flowchart showing an example of the operation of howling detection apparatus **100***d*, and corresponds to FIG. **2** of Embodiment 1. Parts in FIG. **11** identical to those in FIG. **2** are assigned the same step numbers as in FIG. **2**, and descriptions thereof are omitted here.

If the first counter value exceeds the second threshold value (S**1700**: YES), howling determination section **340** of howling detection section **300** proceeds to step S**1800***d*. Then, in step S**1800***d*, howling determination section **340** outputs a first determination result indicating that howling has occurred to howling comprehensive determination section **600***d*.

If the first counter value does not exceed the second threshold value (S**1700**: NO), howling determination section **340** of howling detection section **300** proceeds to step S**1900***d*. Then, in step S**1900***d*, howling determination section **340** outputs a first determination result indicating that howling has not occurred to howling comprehensive determination section **600***d*.

Then, in step S**1910***d*, frequency peak detection section **500***d* performs frequency peak detection processing. Frequency peak detection processing is processing that determines whether or not howling has occurred in an input signal based on the presence or absence of a frequency peak in the input signal.

Frequency peak detection section **500***d* may also perform frequency peak detection processing before, or at the same time as, the processing up to the first determination by howling detection section **300** (S**1100** through S**1900***d*). In this case also, frequency peak detection section **500***d* performs frequency peak detection processing in the same cycle as the howling detection section **300** determination cycle, that is, every sample or every frame (plurality of samples).

FIG. **12** is a flowchart showing an example of frequency peak detection processing.

First, in step S**1911***d*, frequency analysis section **510***d* extracts a frequency component for each of a plurality of band divisions from the input signal.

Then, in step S**1912***d*, level calculation section **520***d* calculates the input signal level of each frequency component from the plurality of frequency components.

Then, in step S**1913***d*, average level calculation section **530***d* calculates an average level from the input signal levels of the plurality of frequency components. At this time, average level calculation section **530***d* may weigh the plurality of frequency component input signal levels in calculating the average level.

Then, in step S**1914***d*, level ratio calculation section **540***d* calculates a level ratio for each frequency component from the plurality of frequency component input signal levels and the average level.

Then, in step S**1915***d*, howling determination section **550***d* determines for each frequency component whether or not its level ratio exceeds a predetermined fifth threshold value.

Here, the value set as the fifth threshold value is a value making it possible to determine that the above level ratio stands out in comparison with other frequency components.

Howling determination section **550***d* proceeds to step S**1916***d* for a frequency component for which the level ratio exceeds the fifth threshold value, or proceeds to step S**1917***d* for a frequency component for which the level ratio does not exceed the fifth threshold value.

In step S**1916***d*, howling determination section **550***d* increments a relevant third counter value among third counter values prepared for each frequency component, and proceeds to step S**1918***d*.

In step S**1917***d*, howling determination section **550***d* resets the relevant third counter value and proceeds to step S**1918***d*.

That is to say, a third counter value indicates the length of time for which peaks occur continuously in the corresponding frequency component.

In step S**1918***d*, howling determination section **550***d* determines whether or not the third counter value of any frequency component exceeds a predetermined sixth threshold value.

Here, the sixth threshold value is a value equivalent to a predetermined time shorter than a howling interval and longer than the duration of a noise state, and is a value equivalent to 0.5 second to 1 second, for example.

If the third counter value exceeds the sixth threshold value (S**1918***d*: YES), howling determination section **550***d* proceeds to step S**1919***d*. If the third counter value does not exceed the sixth threshold value (S**1918***d*: NO), howling determination section **550***d* proceeds to step S**1920***d*.

In step S**1919***d*, howling determination section **550***d* outputs a second determination result indicating that howling has occurred to howling comprehensive determination section **600***d*, and returns to the processing in FIG. **11**.

In step S**1920***d*, howling determination section **550***d* outputs a second determination result indicating that howling has not occurred to howling comprehensive determination section **600***d*, and returns to the processing in FIG. **11**.

In step S**1930***d* in FIG. **11**, howling comprehensive determination section **600***d* inputs the first determination result from howling detection section **300** and the second determination result from frequency peak detection section **500***d*. Then howling comprehensive determination section **600***d* performs comprehensive determination of whether or not howling has occurred based on the first determination result and second determination result.

If both the first determination result and the second determination result show a determination result indicating that howling has occurred (S**1930***d*: YES), howling comprehensive determination section **600***d* proceeds to step S**1940***d*. If at least one of the first determination result and the second determination result does not show a determination result indicating that howling has occurred (S**1930***d*: NO), howling comprehensive determination section **600***d* proceeds to step S**1950***d*.

In step S**1940***d*, howling comprehensive determination section **600***d* makes a comprehensive determination that howling has occurred, outputs a determination result indicating this to output terminal **400**, and proceeds to step S**2000**.

In step S**1950***d*, howling comprehensive determination section **600***d* makes a comprehensive determination that howling has not occurred, and proceeds directly to step S**2000**.

By means of such processing, howling detection apparatus **100***d* can output a result combining a determination result from howling detection section **300** and a determination result from frequency peak detection section **500***d* as a final determination result.

By performing howling detection using not only a threshold value in accordance with a noise level but also a frequency peak in this way, howling detection apparatus **100***d* according to this embodiment can reduce erroneous detection of howling.

A provision may also be made for howling determination section **550***d* to acquire peak frequency information indicating which frequency band a frequency peak occurs in, that is, a frequency band for which the third counter value exceeds the sixth threshold value. In this case, it is possible for howling detection apparatus **100***d* to detect which frequency band howling occurs in.

Howling comprehensive determination section **600***d* may also measure the duration of a state in which both the first determination result and the second determination result indicate the occurrence of howling. Then howling comprehensive determination section **600***d* may determine that howling has occurred on the condition that this duration exceeds a predetermined seventh threshold value.

Also, howling comprehensive determination section **600***d* may determine that howling has occurred on the condition that the difference between the time for which the first determination result indicates the occurrence of howling and the time for which the second determination result indicates the occurrence of howling is within a predetermined range. By performing such determination, howling comprehensive determination section **600***d* can further improve the accuracy of howling detection.

(Embodiment 3)

Embodiment 3 of the present invention is an example of a howling suppression apparatus that performs howling suppression using a howling detection apparatus according to Embodiment 1.

FIG. **13** is a block diagram showing the configuration of a howling suppression apparatus according to this embodiment, and corresponds to FIG. **1** of Embodiment 1. Parts in FIG. **13** identical to those in FIG. **1** are assigned the same reference signs as in FIG. **1**, and descriptions thereof are omitted here.

As shown in FIG. **13**, howling suppression apparatus **700***e* according to this embodiment includes input terminal **200**, A/D converter **710***e*, howling detection apparatus **100** according to Embodiment 1, subtracter **720***e*, delay device **730***e*, adaptive filter **740***e*, D/A converter **750***e*, and output terminal **400***e*.

Input terminal **200** outputs an input signal to A/D converter **710***e*.

A/D converter **710***e* performs A/D conversion of the input signal from an analog signal to a digital signal, and outputs the converted input signal to howling detection apparatus **100** and subtracter **720***e*.

Howling detection apparatus **100** performs howling detection from the input signal, and outputs the detection result not to output terminal **400***e* but to adaptive filter **740***e*.

Subtracter **720***e* calculates the difference between the input signal input from A/D converter **710***e* and a filter output signal input from adaptive filter **740***e* described later herein. Then subtracter **720***e* outputs the calculated difference to delay device **730***e*, adaptive filter **740***e*, and D/A converter **750***e*. That is to say, the input signal is a target signal, and the difference is an error signal.

Delay device **730***e* generates a signal resulting from delaying the error signal, and outputs the generated signal to adaptive filter **740***e* as a reference signal of adaptive filter **740***e* described later herein. Here, the delay amount of delay device **730***e* is assumed to be set to a value such that target signal (input signal) of subtracter **720***e* and the reference signal (filter input signal) control signal cease to have a mutual correlation.

Adaptive filter **740***e* sequentially updates the filter coefficient so that the mean square value of the error signal becomes minimal. Then adaptive filter **740***e* performs convolution of the reference signal and the filter coefficient, and outputs the signal subtracter **720***e* as a filter output signal.

When adaptive filter **740***e* outputs a signal that simulates a feedback signal looping from the speaker to the microphone, the mean square value of the error signal becomes minimal. Therefore, the above filter coefficient updating by adaptive filter **740***e* means performing estimation of the transfer characteristics of an acoustic feedback path between the speaker and the microphone.

In this embodiment, the result of such filter updating is that an adaptive filter **740***e* output signal simulating a feedback signal is deducted from a target signal including a feedback signal, and howling is suppressed. Various kinds of known algorithms, such as an NLMS (normalized least mean square) algorithm, can be used as a filter coefficient update algorithm.

Adaptive filter **740***e* enters a howling suppression mode on the condition that a howling detection result from howling detection apparatus **100** shows a determination result indicating that howling has occurred.

Here, a howling suppression mode is a mode in which filter coefficient updating is performed, or the speed of filter coefficient updating is increased. Therefore, adaptive filter **740***e* can update a filter coefficient at high speed until howling converges only when howling occurs.

D/A converter **750***e* performs D/A conversion of an error signal from a digital signal to an analog signal, and outputs the converted signal to output terminal **400***e*.

Output terminal **400***e* is a terminal for connection to an acoustic apparatus such as an amplifier having a function of outputting speech from a speaker.

Howling suppression apparatus **700***e* can be configured, for example, by means of a computer that includes a CPU, a storage medium such as RAM, and so forth. Also, howling suppression apparatus **700***e* may have a configuration in which input terminal **200**, A/D converter **710***e*, D/A converter **750***e*, and output terminal **400***e* are omitted.

Thus, howling suppression apparatus **700***e* according to this embodiment can suppress howling by canceling a feedback signal looping from a speaker to a microphone using an adaptive filter.

Also, howling suppression apparatus **700***e* automatically calculates a threshold value for howling detection according to the acoustic environment in which it is used, and controls the on/off state or filter coefficient updating speed of the adaptive filter according to the detection result. By this means, howling suppression apparatus **700***e* can perform howling suppression while avoiding a volume change and sound quality change as far as possible when howling does not occur.

Howling suppression apparatus **700***e* may also have a configuration in which howling detection apparatus **100***d* according to Embodiment 2 is provided instead of howling detection apparatus **100** according to Embodiment 1.

(Embodiment 4)

Embodiment 4 of the present invention is an example of howling suppression apparatus that performs howling suppression by locally reducing frequency band gain.

FIG. **14** is a block diagram showing the configuration of a howling suppression apparatus according to this embodiment, and corresponds to FIG. **13** of Embodiment 3. Parts in FIG. **14** identical to those in FIG. **13** are assigned the same reference signs as in FIG. **13**, and descriptions thereof are omitted here.

In FIG. **14**, howling suppression apparatus **700***f* includes input terminal **200**, A/D converter **710***e*, howling detection apparatus **100***d* according to Embodiment 2, howling suppression section **760***f*, D/A converter **750***e*, and output terminal **400***e*.

A/D converter **710***e* outputs an A/D-converted input signal to howling detection apparatus **100***d* and howling suppression section **760***f*.

Howling detection apparatus **100***d* performs howling detection from the input signal, and outputs the detection result not to output terminal **400***e* but to howling suppression section **760***f*. Also, when having determined that howling has occurred, howling detection apparatus **100***d* identifies a frequency band in which a peak has occurred (for example, a frequency band for which the third counter value has exceeded the sixth threshold value, hereinafter referred to as a "peak frequency band"), and outputs peak frequency information indicating the peak frequency band to howling suppression section **760***f*.

According to this embodiment, it is assumed that howling detection apparatus **100***d* outputs peak frequency information to howling suppression section **760***f* when having determined that howling has occurred. It is also assumed that howling detection apparatus **100***d* performs notification of howling occurrence and notification of the frequency band in which a peak occurred with peak frequency information output.

Howling suppression section **760***f* outputs the input signal to D/A converter **750***e*. When peak frequency information is input from howling detection apparatus **100***d*, howling suppression section **760***f* reduces the gain of the peak frequency band indicated by the peak frequency information with respect to the input signal using a notch filter. As a result, the gain of the frequency band in which howling occurs is reduced, and howling is suppressed.

Howling suppression apparatus **700***f* can be configured, for example, by means of a computer that includes a CPU, a storage medium such as RAM, and so forth. Also, howling suppression apparatus **700***f* may have a configuration in which input terminal **200**, A/D converter **710***e*, D/A converter **750***e*, and output terminal **400***e* are omitted.

Thus, howling suppression apparatus **700***f* according to this embodiment can maintain the gain of another frequency

band as far as possible by locally reducing the gain of a frequency band in which howling occurs, and can suppress howling.

Also, howling suppression apparatus **700***f* automatically calculates a threshold value for howling detection according to the acoustic environment in which it is used, and controls the on/off state of gain reduction according to the detection result. By this means, howling suppression apparatus **700***f* can perform howling suppression while avoiding a volume change and sound quality change as far as possible when howling does not occur.

Howling suppression section **760***f* may also convert or divide an input signal into a plurality of frequency components, and reduce peak frequency band gain by performing frequency combination into a temporal signal again after reducing the gain of a frequency band in which howling occurs.

(Other Embodiments)

Embodiments of the present invention are not limited to above-described Embodiment 1 through Embodiment 4. In particular, hardware configurations of an apparatus implementing the present invention may be as follows, for example.

(1) All or part of a howling detection apparatus and howling suppression apparatus is configured by means of a computer system having a microprocessor, ROM (read only memory), RAM, a hard disk unit, and so forth. In this case, a computer program that achieves the same kind of operation as the above-described sections is stored in the RAM or hard disk unit. The functions of the above-described sections are then implemented by having the microprocessor operate in accordance with the computer program.

(2) All or part of a howling detection apparatus and howling suppression apparatus is configured by means of a single system LSI (large scale integration circuit). A system LSI is a super-multifunction LSI constructed by integrating a plurality of configuration parts on a single chip, and more specifically, is a computer system configured with the inclusion of a microprocessor, ROM, RAM, and so forth. In this case, a computer program that achieves the same kind of operation as the above-described sections is stored in RAM or a hard disk unit. The functions of the above-described sections are then implemented by having the microprocessor operate in accordance with the computer program.

(3) All or part of a howling detection apparatus and howling suppression apparatus is configured by means of a removable IC card or unit module. An IC card or module is a computer system configured with the inclusion of a microprocessor, ROM, RAM, and so forth. An IC card or module may be configured with the inclusion of an above super-multifunction LSI. In these cases, the functions of the above-described sections are implemented by having the microprocessor operate in accordance with a computer program. It is desirable for an IC card or module to be tamper-proof.

The category of the present invention is not limited to a physical invention. That is to say, the present invention can be considered as the whole or a part of a method and processing implemented by a howling detection apparatus and howling suppression apparatus rather than a howling detection apparatus and howling suppression apparatus themselves. In this case, the present invention can have the following kinds of aspects.

(4) The present invention is composed of a computer program that implements the above method and processing.

(5) The present invention is composed of a digital signal that stipulates the above computer program. In this case, the computer program can be transmitted via an electrical communication line, a radio communication line, a cable communication line, a network such as the Internet, data broadcasting, or the like, and executed in another computer system independent of the transmission source.

(6) The present invention is composed of an entity that is recorded on a computer-readable recording medium that records the above digital signal. Computer-readable storage media include, for example, a flexible disk, hard disk, CD-ROM, MO (magnet-optics), DVD (digital video disc), DVD-ROM, DVD-RAM, BD (blu-ray disc), semiconductor memory, and so forth. In this case, the computer program can be transferred by transfer of the recording medium, and executed in another computer system independent of the transmission source.

The disclosure of Japanese Patent Application No. 2011-051623, filed on Mar. 9, 2011, including the specification, drawings and abstract, is incorporated herein by reference in its entirety.

INDUSTRIAL APPLICABILITY

The present invention is suitable for use as a howling detection apparatus, howling suppression apparatus, and howling detection method capable of detecting the occurrence of howling with a higher degree of accuracy. More particularly, the present invention is suitable for use in a device that is prone to the occurrence of howling and whose usage environment is not constant, such as a hearing aid or karaoke apparatus.

REFERENCE SIGNS LIST

100, **100***d* Howling detection apparatus
200 Input terminal
300 Howling detection section
310 Signal level calculation section
320 Level fluctuation estimated value calculation section
330 Threshold value calculation section
340 Howling determination section
400, **400***e* Output terminal
500*d* Frequency peak detection section
510*d* Frequency analysis section
520*d* Level calculation section
530*d* Average level calculation section
540*d* Level ratio calculation section
550*d* Howling determination section
600*d* Howling comprehensive determination section
700*e*, **700***f* Howling suppression apparatus
710*e* A/D converter
720*e* Subtracter
730*e* Delay device
740*e* Adaptive filter
750*e* D/A converter
760*f* Howling suppression section

The invention claimed is:

1. A howling detection apparatus comprising:

a signal level calculation section that calculates, from an input signal, an input signal level that is a signal level of said input signal at a predetermined time;

a level fluctuation estimated value calculation section that calculates a level fluctuation estimated value by multiplying a previous level fluctuation estimated value by a predetermined coefficient such that the level fluctuation estimated value gradually increases or gradually decreases by a predetermined amount from said input signal level over time, the predetermined coefficient being determined in accordance with the input signal level;

a threshold value calculation section that calculates, from said level fluctuation estimated value, a level threshold value by changing the level threshold value according to said level fluctuation estimated value; and

a howling determination section that determines that howling has occurred in the input signal on a condition that a state in which said input signal level exceeds said level threshold value continues in excess of a predetermined time threshold value.

2. The howling detection apparatus according to claim **1**, wherein said level fluctuation estimated value is one of the following: a value that gradually increases by a predetermined amount from a minimum value of said input signal level, a value that gradually decreases by a predetermined amount from a maximum value of said input signal level, or a value that gradually increases or gradually decreases by a predetermined amount from an average value of said input signal level.

3. The howling detection apparatus according to claim **2**, wherein said level fluctuation estimated value is a value that is sequentially updated in accordance with a transition of said input signal level, and performs tracking in a state in which an update amount per said predetermined time is limited.

4. The howling detection apparatus according to claim **3**, wherein:

said update amount includes an increase amount;

said level fluctuation estimated value calculation section takes a transition of a minimum value of said input signal level as said transition of said input signal level; and

said threshold value calculation section takes a value obtained by multiplying said level fluctuation estimated value by a value exceeding 1, or a value obtained by adding a value exceeding 0 to said level fluctuation estimated value, as said level threshold value.

5. The howling detection apparatus according to claim **4**, wherein said level fluctuation estimated value calculation section tracks said level fluctuation estimated value for said input signal level without limiting said increase amount in a rise of said input signal level.

6. The howling detection apparatus according to claim **3**, wherein:

said update amount includes a decrease amount;

said level fluctuation estimated value calculation section takes a transition of a maximum value of said input signal level as the transition of said input signal level; and

said threshold value calculation section takes a value obtained by multiplying said level fluctuation estimated value by a value exceeding 0 and less than 1, or a value obtained by subtracting a value exceeding 0 from said level fluctuation estimated value, as said level threshold value.

7. The howling detection apparatus according to claim **3**, wherein:

said update amount includes an increase amount;

said level fluctuation estimated value calculation section takes a transition of a long-term average value of said input signal level as said transition of said input signal level; and

said threshold value calculation section takes a value obtained by multiplying said level fluctuation estimated value by a value greater than or equal to 1, or a value obtained by adding a value greater than or equal to 0 to said level fluctuation estimated value, as said level threshold value.

8. The howling detection apparatus according to claim **1**, further comprising:

a frequency peak detection section that determines whether or not howling has occurred in said input signal based on presence or absence of a frequency peak of said input signal; and

a howling comprehensive determination section that performs final determination that howling has occurred, on the condition that said howling has been determined to have occurred by both said howling determination section and said frequency peak detection section.

9. The howling detection apparatus according to claim **8**, wherein said howling comprehensive determination section performs final determination that howling has occurred, on the condition that a difference between a time for which said howling determination section determines said howling to have occurred and a time for which said frequency peak detection section determines said howling to have occurred is within a predetermined range.

10. A howling suppression apparatus comprising:

the howling detection apparatus according to claim **1**; and

a howling suppression section that performs processing to suppress said howling for said input signal when said howling detection apparatus determines that said howling has occurred.

11. The howling suppression apparatus according to claim **10**, wherein said howling suppression section uses an adaptive filter corresponding to a transfer characteristic of an acoustic feedback path of said input signal.

12. The howling suppression apparatus according to claim **10**, wherein said howling suppression section reduces a gain of a frequency band in which a frequency peak of said input signal occurs.

13. A howling detection method comprising:

calculating, from an input signal, an input signal level that is a signal level of said input signal at a predetermined time;

calculating a level fluctuation estimated value by multiplying a previous level fluctuation estimated value by a predetermined coefficient such that the level fluctuation estimated value gradually increases or gradually decreases by a predetermined amount from said input signal level over time, the predetermined coefficient being determined in accordance with the input signal level;

calculating, from said level fluctuation estimated value, a level threshold value by changing the level threshold value according to said level fluctuation estimated value; and

determining that howling has occurred in the input signal on a condition that a state in which said input signal level exceeds said level threshold value continues in excess of a predetermined time threshold value.

* * * * *